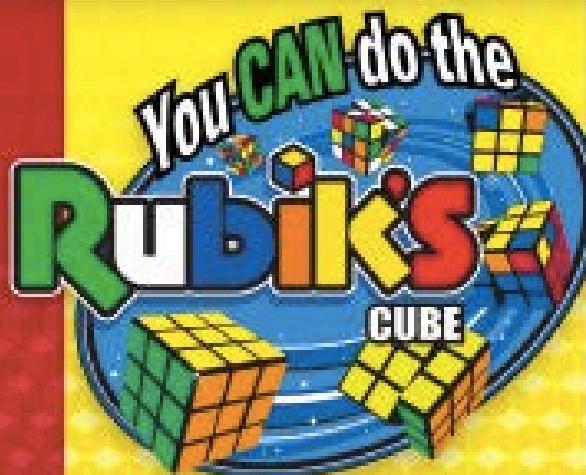


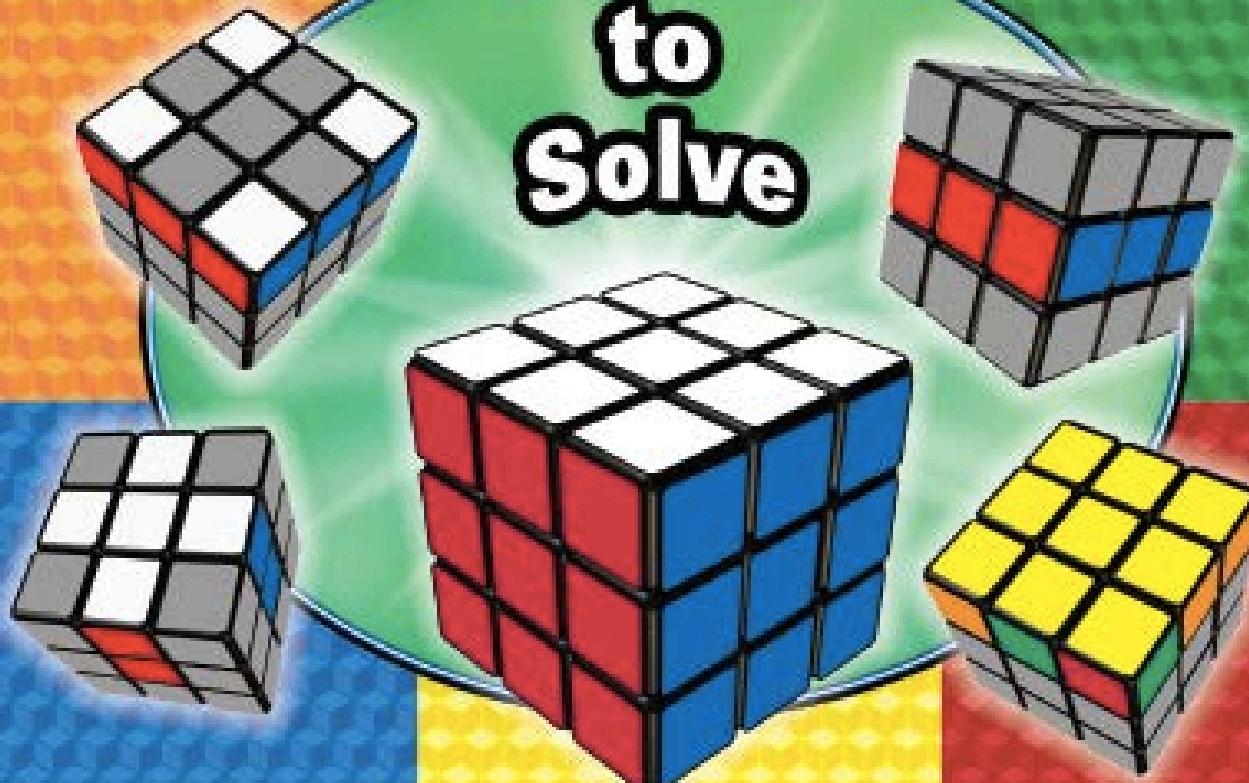


LEARN TO SOLVE THE RUBIK'S® CUBE

Updated Stages
2 & 3



Learn to Solve

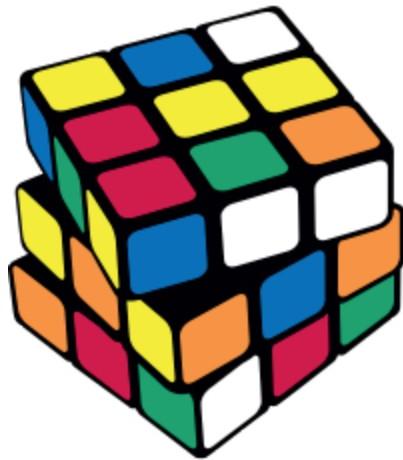


Lessons include:

- Meet the Cube
- The WHITE Cross
- The WHITE Corners
- The MIDDLE Layer
- The YELLOW Face
- Positioning the YELLOW Corners & Edges



Learn to Solve



A Curriculum for Teaching How to Solve
The
Rubik's® Cube

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21st Century Learning Skills		
Learning & Innovation Skills: <ul style="list-style-type: none"> • Creativity and Innovation • Critical Thinking and Problem Solving • Communication and Collaboration 	Life & Career Skills: <ul style="list-style-type: none"> • Flexibility and Adaptability • Initiative and Self Direction • Social and Cross-Cultural Skills • Productivity and Accountability • Leadership and Responsibility 	Media Literacy: <ul style="list-style-type: none"> • Information Literacy



Meeting the Cube

Lesson 1



Lesson Focus

In this lesson, you will learn:



- the parts of the cube
- how to move the cube
- what the moves are called
- what an inverse move is

[Vocabulary](#) [Lesson Focus](#) [Activities](#) [Answers](#)

CONTENT STANDARDS & SKILLS: LESSON 1

Grade	Common Core	National Council of Teachers of Mathematics
K - 2	<p>K.CC.5 - Answer "How Many Questions. K.MD.1 - Measurable attributes of objects K.G.1 - Describe the relative positions of these objects using terms such as <i>above</i>, <i>below</i>, <i>beside</i>, <i>in front of</i>, <i>behind</i>, and <i>next to</i>. K.G.3 - Identify shapes as two-dimensional K.G.4 - Compare two- and three-dimensional shapes 1.G.1 -Defining attributes of shapes 2.G.2 -Partition a rectangle into rows and columns of same size squares</p>	<p>Number and Operations • recognize "how many" in sets of objects Algebra • sort, classify, and order objects by properties Geometry • recognize, name, build, draw, compare, and sort two- and three- dimensional shapes, • describe attributes and parts of two- and three- dimensional shapes, • recognize shapes from different perspectives</p>
3 - 5	<p>3.MD.1 - Telling time 4.G.1 -Identify angles, perpendicular and parallel lines in two-dimensional figures 5.NF.4b - Area of a rectangle using unit squares 5 .MD.3 - Volume of a cube 5.G.3 - Attributes of two-dimensional figures</p>	<p>Geometry • identify attributes of two- and three-dimensional objects; develop vocabulary to describe the attributes. • understand relationships among angles, side lengths, perimeters, area, and volume. • describe objects and patterns Measurement • understand attributes such as length, area, weight, and volume</p>
6 - 8	<p>6.G.2 - Volume of a right rectangular prism</p>	<p>Geometry • precisely describe two- and three-dimensional objects using their attributes. • use two- dimensional representations of three- dimensional objects to solve volume and surface problems Measurement • select appropriate units to measure perimeter, area, surface area, and volume</p>

Meeting the Cube

Lesson 1



Lesson Content:

The questions on these slides are meant to focus students on the characteristics of the Rubik's Cube. Depending on the grade level of your students, these questions may or may not be appropriate. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation.



- What shape is this object?
- Each side is called a *face*. What shape is each face?
- What angle measures do the faces make?
- The face colors are important when solving the cube. What colors are opposite each other?

Vocabulary Lesson Focus Lesson Pages Rubik's Cube

Slides 3 - 4

- Cube. Compare squares and cubes.
- The term **face** will be used throughout the *You CAN Do the Rubik's Cube* materials so you will want to make sure your students understand this term.
- 90° Turns of faces will be described as **$\frac{1}{4}$ turn**, **$\frac{1}{4}$ rotation**, or **90° turn**. You may want to explain this terminology with your students before you begin.
- WHITE is opposite YELLOW.
BLUE is opposite GREEN.
RED is opposite ORANGE.



- What is the length of a side?
- What is the distance around the rim or border of a face?
- How many squares cover one face?
- Does the cube weigh more or less than an apple?

Vocabulary Lesson Focus Lesson Pages Rubik's Cube

- 3 nonstandard units (sides of the tiles) Perhaps you want students to practice with standard measurement.
- 12 units. Perimeter contains the words "rim" and "meter". Have you used these cues to help students remember the meaning of perimeter?
- 9 sq units
- Answers may vary.

Meeting the Cube

Lesson 1



Slides 5 - 6

Each face of a Rubik's Cube has a name. The name depends on how you are holding the cube.

Up Face Down Face
Left Face Right Face
Front Face Back Face

Vocabulary Lesson Focus Lesson Plans More Lessons

Lateral Face
The sides of a cube – LEFT, RIGHT, FRONT, or BACK

FRONT RIGHT

What color is the LEFT face?

The UP and DOWN faces are bases, not lateral faces.

Vocabulary Lesson Focus Lesson Plans More Lessons



Turning the UP and DOWN faces is like opening and closing a jar or screwing in a lightbulb. This imagery helps students orient the cube.



Grab hold of the handle of a mug to turn the LEFT and RIGHT faces. Taking a sip turns the cup toward you. Dump the cup out by turning it away from you.



The FRONT and BACK moves could be imagined as turning a doorknob or combination lock.



You will see reference to these images other slides.

HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.

HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve. It is easier to identify the UP face when the cube is on a flat surface than when it is in moving hands.

You may want to skip the Lateral Face slide with students younger than 5th grade. However, at all grade levels, it is important to stress that the FRONT face is the one facing you. It can be any color.

Meeting the Cube

Lesson 1



Slides 7 - 9

Center pieces have one color. There are 6 center pieces, one in the middle of each face.

Center pieces do not move. They represent the color of their face. When the cube is solved, the face will be the color of the **center** piece.

BLUE Face WHITE Face
ORANGE Face

When this cube is solved, this FACE will be ORANGE.

Vocabulary Lesson Focus Union Review Author's Tools

The important information on this page is that the CENTER tile tells you what color the face will be when the cube is solved.

Have students identify a specific color face. Ask them to identify the color of the opposite face. Students begin to realize that BLUE is always opposite GREEN; RED and ORANGE are always opposite; and WHITE and YELLOW are always opposite.

Edge pieces have two colors because they touch 2 faces. There are 12 edge pieces located between the corners.

YELLO/RED Edge Red/WHITE Edge

Describe each of the edge pieces. (yellow/red)

Vocabulary Lesson Focus Union Review Author's Tools

Stress that EDGE pieces have 2 colors. Ask students what color combinations could **not** be edge pieces. (There will be no BLUE/GREEN edge pieces because BLUE and GREEN are opposite faces, for example.)

Have students “pinch” the EDGE pieces between 2 fingers to emphasize the 2 tiles.

Corner Pieces have 3 colors because they touch 3 faces. There are 8 corner pieces.

GREEN/ORANGE/YELLOW Corner

Describe each of the corner pieces.

Vocabulary Lesson Focus Union Review Author's Tools

Once students start solving, they tend to confuse EDGES and CORNERS. Have students hold the CORNERS with 3 fingers.

You may want to introduce the term vertex with older students. This may help them differentiate the CORNERS from the EDGES. With younger students, have them identify the point that CORNERS have. EDGES do not have points.

Meeting the Cube

Lesson 1



Slides 10 - 11

Clockwise
The direction the hands on a clock move

When we twist the faces of the cube, some of the turns will be clockwise. You'll need to imagine a clock's face on the side of the cube.

Vocabulary Lesson Focus Lesson Review About This

UP Face Move:
a ¼ clockwise turn of the up face

Think of closing a jar or screwing in a lightbulb!

Vocabulary Lesson Focus Lesson Review About This

The clockwise turn is as if you are looking at the face. You may want to put small clock faces on the sides of the cube for younger students. With older students, you may want to use mental imagery of the clock face on the cube face.

HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.

Slides 12 - 13

Vocabulary

Counterclockwise
The opposite of the direction the hands on a clock move

When the face of a Rubik's Cube should be turned counterclockwise, you'll see an "i" following the letter of the face.

Vocabulary Lesson Focus Lesson Review About This

An UPPER Face Counterclockwise Turn uses the abbreviation Ui.

Now you're opening a jar!

- Inverse means opposite.
- By inverting a move, the move is undone.

Vocabulary Lesson Focus Lesson Review About This

A counterclockwise or inverse turn is always indicated by a lowercase i after the face name. There is a slide demonstrating each turn and its inverse.

Meeting the Cube

Lesson 1



Slides 14 - 19 Have students turn their cubes as you go through the slides.

HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.



DOWN Face Move:
a $\frac{1}{4}$ clockwise turn
of the down face



It's like screwing in a lightbulb!

Vocabulary Lesson Focus Lesson Review Rubik's Cube



A DOWN Face Counter-clockwise Turn uses the abbreviation **Di**.



It's a lightbulb move!

- Inverse means opposite.
- By inverting a move, the move is undone.

Vocabulary Lesson Focus Lesson Review Rubik's Cube



LEFT Face Move:
a $\frac{1}{4}$ clockwise turn
of the left face



Grab hold of the cup handle!

Vocabulary Lesson Focus Lesson Review Rubik's Cube



A LEFT Face Counter-clockwise Turn uses the abbreviation **Li**.



How would you undo an **Li** turn?

Vocabulary Lesson Focus Lesson Review Rubik's Cube



RIGHT Face Move:
a $\frac{1}{4}$ clockwise turn
of the right face



A turn is always $\frac{1}{4}$ turn or a 90° turn. If a 180° right turn were needed, it would say **R R**. How would you know to make a $\frac{3}{4}$ turn?

Vocabulary Lesson Focus Lesson Review Rubik's Cube



A RIGHT Face Counter-clockwise Turn uses the abbreviation **Ri**.



To undo an **R** $\frac{1}{4}$ turn,
make an **Ri** $\frac{1}{4}$ turn.

Vocabulary Lesson Focus Lesson Review Rubik's Cube

Meeting the Cube

Lesson 1



Slides 20 - 23 Have students turn their cubes as you go through the slides.

HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.



FRONT Face Move:
a $\frac{1}{4}$ clockwise turn
of the front face



It's like turning the doorknob to open a door.

Vocabulary Lesson Focus Lesson Review Roll & Cover



A FRONT Face Counter-clockwise Turn uses the abbreviation **Fi**.



Imagine turning the doorknob to close the door!

- Inverse means opposite.
- By inverting a move, the move is undone.

Vocabulary Lesson Focus Lesson Review Roll & Cover



BACK Face Move:
a $\frac{1}{4}$ clockwise turn
of the back face



It's a doorknob move!

Vocabulary Lesson Focus Lesson Review Roll & Cover



A BACK Face Counter-clockwise Turn uses the abbreviation **Bi**.



It's a doorknob move!

- Inverse means opposite.
- By inverting a move, the move is undone.

Vocabulary Lesson Focus Lesson Review Roll & Cover

Meeting the Cube

Lesson 1



¼ turn practice

Start with a solved cube. Notice that the first row is repeated 4 times. You should have a solved cube when you're done.

L	L	L	R	L
L	L	L	R	L
L	L	L	R	L
L	L	L	R	L

Vocabulary
Lesson Focus
Lesson Review
Answer Keys

Slides 24 -29 The next series of slides provides practice in making the turns. Some of the slides say you should start with a solved cube. This is not really important although it will make it easier for you (and perhaps your students) to quickly see if everyone has made the correct turns.

If 4 of the same turn or turn sequence have been made, that part of the cube will remain unchanged. At the end of this sequence, the cubes should be back in the starting position.

Hint: Using the military cadence (♪“LEFT, LEFT, LEFT, RIGHT, LEFT”♪) or some other song or rap may be help students learn the turns. See pages 14 and 15 for additional practice suggestions.

<div style="border: 1px solid black; padding: 10px; width: fit-content; margin-bottom: 10px;"> <p>¼ turn practice Start with a solved cube. Repeat the steps below 4 times to get back to a solved cube.</p> <table border="1" style="margin-top: 10px; border-collapse: collapse; text-align: center;"> <tr><td>L</td><td>L</td><td>L</td><td>R</td><td>L</td></tr> <tr><td>L</td><td>L</td><td>L</td><td>R</td><td>L</td></tr> <tr><td>L</td><td>L</td><td>L</td><td>R</td><td>L</td></tr> <tr><td>L</td><td>L</td><td>L</td><td>R</td><td>L</td></tr> </table> </div> <p>At the end of this sequence, the RIGHT face will be turned once counterclockwise from the starting position. The LEFT face will revert back to its original state.</p>	L	L	L	R	L	L	L	L	R	L	L	L	L	R	L	L	L	L	R	L	<div style="border: 1px solid black; padding: 10px; width: fit-content; margin-bottom: 10px;"> <p>¼ turn practice Start with a solved cube. Repeat the steps below 4 times to get back to a solved cube.</p> <table border="1" style="margin-top: 10px; border-collapse: collapse; text-align: center;"> <tr><td>Ui</td><td>Ui</td><td>Ui</td><td>Di</td><td>Ui</td></tr> <tr><td>Ui</td><td>Ui</td><td>Ui</td><td>Di</td><td>Ui</td></tr> <tr><td>Ui</td><td>Ui</td><td>Ui</td><td>Di</td><td>Ui</td></tr> <tr><td>Ui</td><td>Ui</td><td>Ui</td><td>Di</td><td>Ui</td></tr> </table> </div> <p>At the end of this sequence, the DOWN face will be turned once counterclockwise from the starting position. The UP face will revert back to its original state.</p>	Ui	Ui	Ui	Di	Ui	Ui	Ui	Ui	Di	Ui	Ui	Ui	Ui	Di	Ui	Ui	Ui	Ui	Di	Ui
L	L	L	R	L																																					
L	L	L	R	L																																					
L	L	L	R	L																																					
L	L	L	R	L																																					
Ui	Ui	Ui	Di	Ui																																					
Ui	Ui	Ui	Di	Ui																																					
Ui	Ui	Ui	Di	Ui																																					
Ui	Ui	Ui	Di	Ui																																					
<div style="border: 1px solid black; padding: 10px; width: fit-content; margin-bottom: 10px;"> <p>¼ turn practice Start with a solved cube. Repeat the steps below 4 times to get back to a solved cube.</p> <table border="1" style="margin-top: 10px; border-collapse: collapse; text-align: center;"> <tr><td>Bi</td><td>Bi</td><td>Bi</td><td>Fi</td><td>Bi</td></tr> <tr><td>Bi</td><td>Bi</td><td>Bi</td><td>Fi</td><td>Bi</td></tr> <tr><td>Bi</td><td>Bi</td><td>Bi</td><td>Fi</td><td>Bi</td></tr> <tr><td>Bi</td><td>Bi</td><td>Bi</td><td>Fi</td><td>Bi</td></tr> </table> </div> <p>At the end of this sequence, the BACK face will be turned once counterclockwise from the starting position. The FRONT face will revert back to its original state.</p>	Bi	Bi	Bi	Fi	Bi	Bi	Bi	Bi	Fi	Bi	Bi	Bi	Bi	Fi	Bi	Bi	Bi	Bi	Fi	Bi	<p>Do as many of these turn practices as needed. The goal is to realize that clockwise and counterclockwise will turn differently depending on the face. Remember, the clock is on the face you are turning!</p>																				
Bi	Bi	Bi	Fi	Bi																																					
Bi	Bi	Bi	Fi	Bi																																					
Bi	Bi	Bi	Fi	Bi																																					
Bi	Bi	Bi	Fi	Bi																																					

Meeting the Cube

Lesson 1



Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Please modify your presentation as best meets the needs of your students.

REVIEW: Slides 30 - 34

REVIEW



FACES

Name each face.

Front Face Right Face
Down Face Up Face
Left Face Back Face

Vocabulary Lesson Focus Lesson Review Previous Page

The names of the faces appear on click. The order is random.

REVIEW



How are the faces named?



Name the faces, starting with the top and moving clockwise.

Vocabulary Lesson Focus Lesson Review Previous Page

Remember, BLUE is opposite GREEN.
ORANGE is opposite RED.
WHITE is opposite YELLOW.

REVIEW



What are these pieces called?



How many are there on a cube?

Vocabulary Lesson Focus Lesson Review Previous Page

Remember, EDGE pieces have 2 colored tiles.

There are 12 edge pieces on a Rubik's Cube.

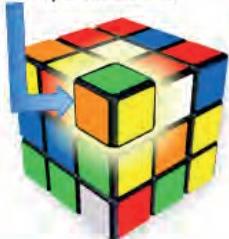
Meeting the Cube

Lesson 1



REVIEW

What is this piece called?



Vocabulary

Lesson Focus

Lesson Review

Lesson Close

Remember, CORNER pieces have a point or vertex. They have 3 tiles. (3 colors)



REVIEW

$\frac{1}{4}$ Turns

R R_i L L_i
D D_i U U_i
B B_i F F_i



- Inverse means opposite.
- By inverting a move, the move is undone.

Vocabulary

Lesson Focus

Lesson Review

Lesson Close

Turns are always $\frac{1}{4}$ rotations or 90° . The opposite or inverse of a turn is always indicated by a lowercase *i* following the abbreviation for the name of the face. See pages 14 and 15 for additional $\frac{1}{4}$ rotation practice ideas.

Vocabulary: Slides 35 - 36



Vocabulary

Cube: 3 dimensional object with 6 square surfaces that are the same size



Face: 2 dimensional surface of a cube

CENTER: The piece in the middle of a face. Face colors are the color of the CENTER.



CORNER: The piece where 3 faces meet

Vocabulary

Lesson Focus

Lesson Review

Lesson Close



Vocabulary

EDGE: The piece between the corners. An edge piece has 2 colors.



Turn (move): a $\frac{1}{4}$ clockwise turn of a face of the Cube. A turn is 90° .



Inverse: an opposite action. The inverse of a move undoes the move.

Vocabulary

Lesson Focus

Lesson Review

Lesson Close



Math Connection: Slide 37

Lesson Extension:

RIGHT ANGLE

A 90 degree angle. A $\frac{1}{4}$ turn of a Rubik's® Cube is 90° .

Vocabulary Lesson Focus Previous Lessons Next Lessons

With younger students, a right angle is often described as a “square” corner. With a Rubik’s Cube, you can begin to develop an understanding of angle as a measure of turning.

A connection to 90° angle as a $\frac{1}{4}$ turn is another way to view fractions as part of a whole. A whole turn is 360° .

Trivia: Slide 38

You CAN do the Rubik's® CUBE

Question: The Rubik's Cube was created in 1974.
How old is the Rubik's Cube now?

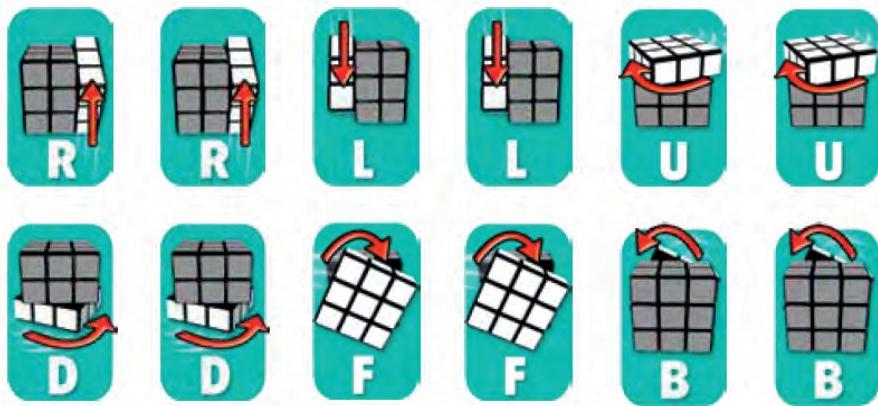
Answer: As of 2018, the Rubik's Cube is 44 years old.

Vocabulary Lesson Focus Previous Lessons Next Lessons

This could be the beginning of a class book, student journal, research project, or bulletin board.

$\frac{1}{4}$ Turn Practice

Multicolored Cross (if you begin with a solved cube)



To return to a solved state



Square in the Middle (if you begin with a solved cube)

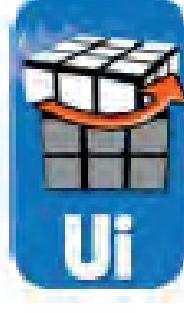
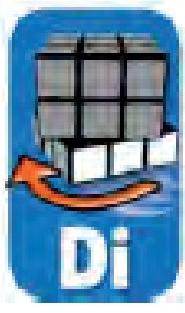
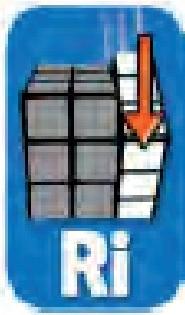


Return to a solved state



Create Your Own Practice Patterns

Cubes can be in any state to do this activity. Use the images on the next page to create cards. Students can create a series of $\frac{1}{4}$ turn sequences for one another. Have them create the “undo” sequence as well to return the cube to its original state. Have students record their sequences so that they become familiar with the notation for the turns.





$\frac{1}{4}$ Turns

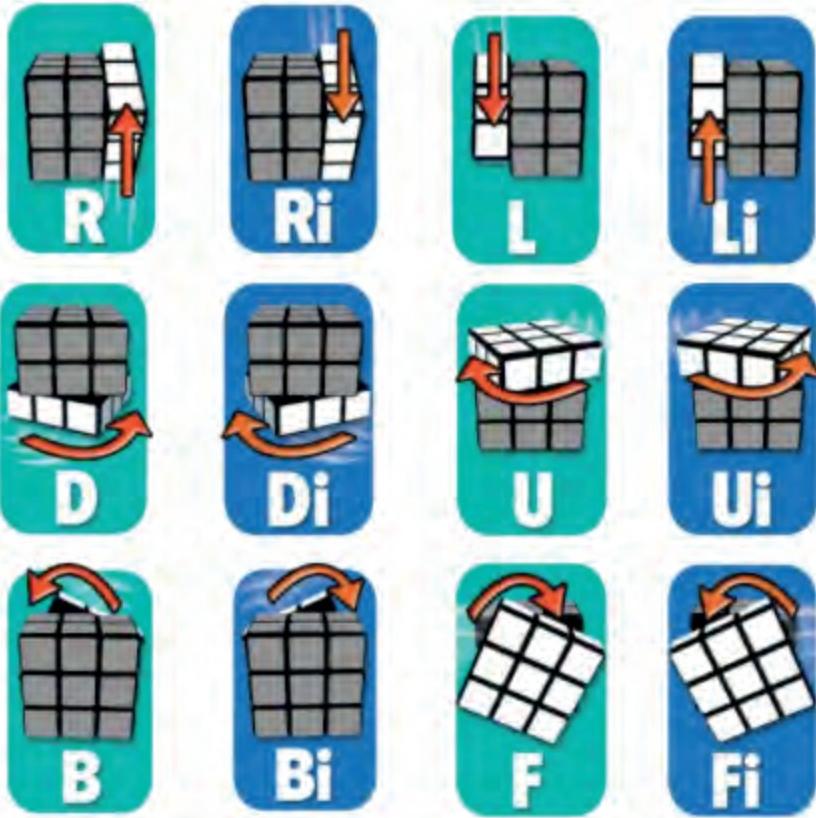
R	Ri	L	Li
D	Di	U	Ui
B	Bi	F	Fi

A $\frac{1}{4}$ turns is clockwise unless an "i" follows the letter. Then the turn is counter-clockwise.

SO...

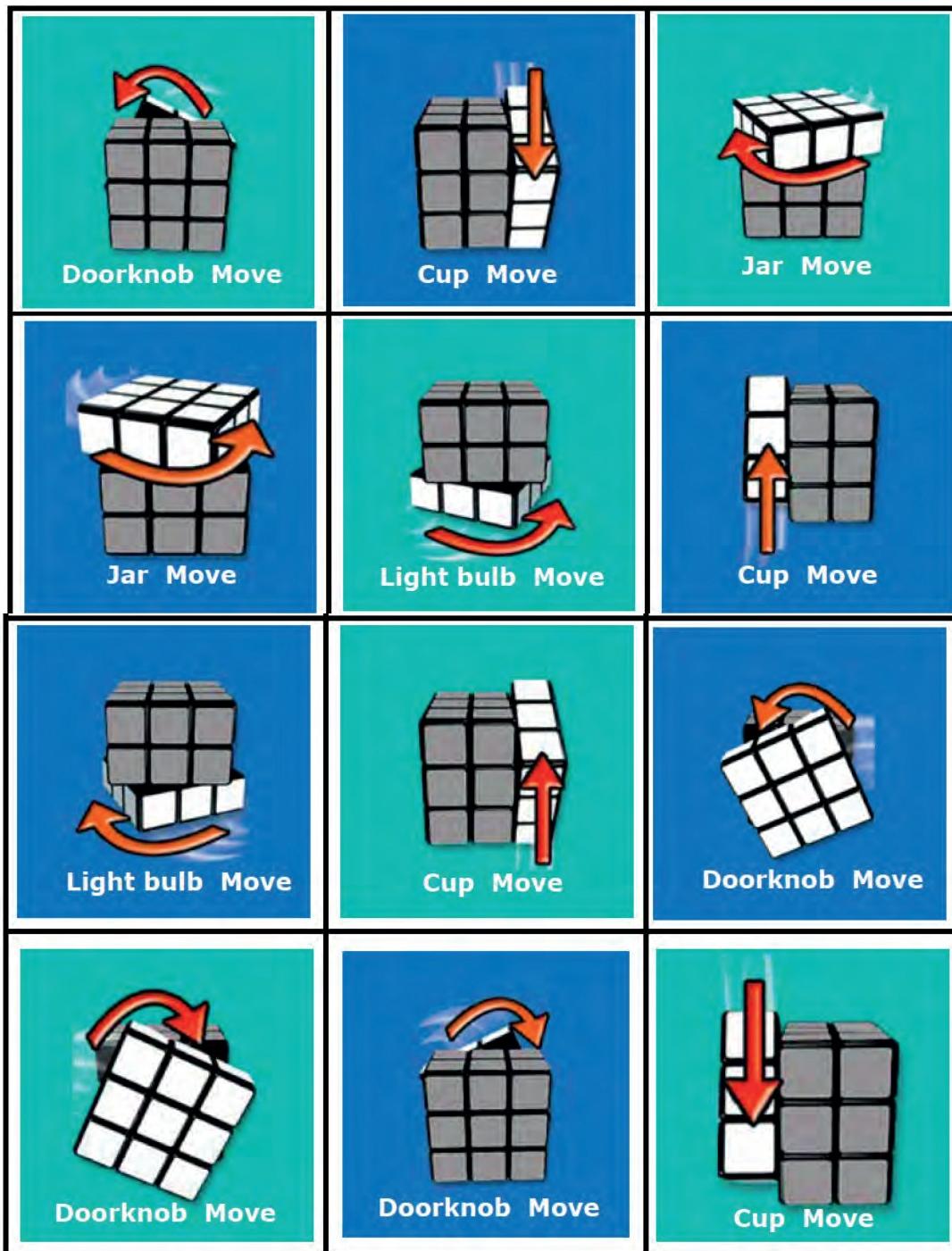
R is a clockwise turn of the RIGHT face.

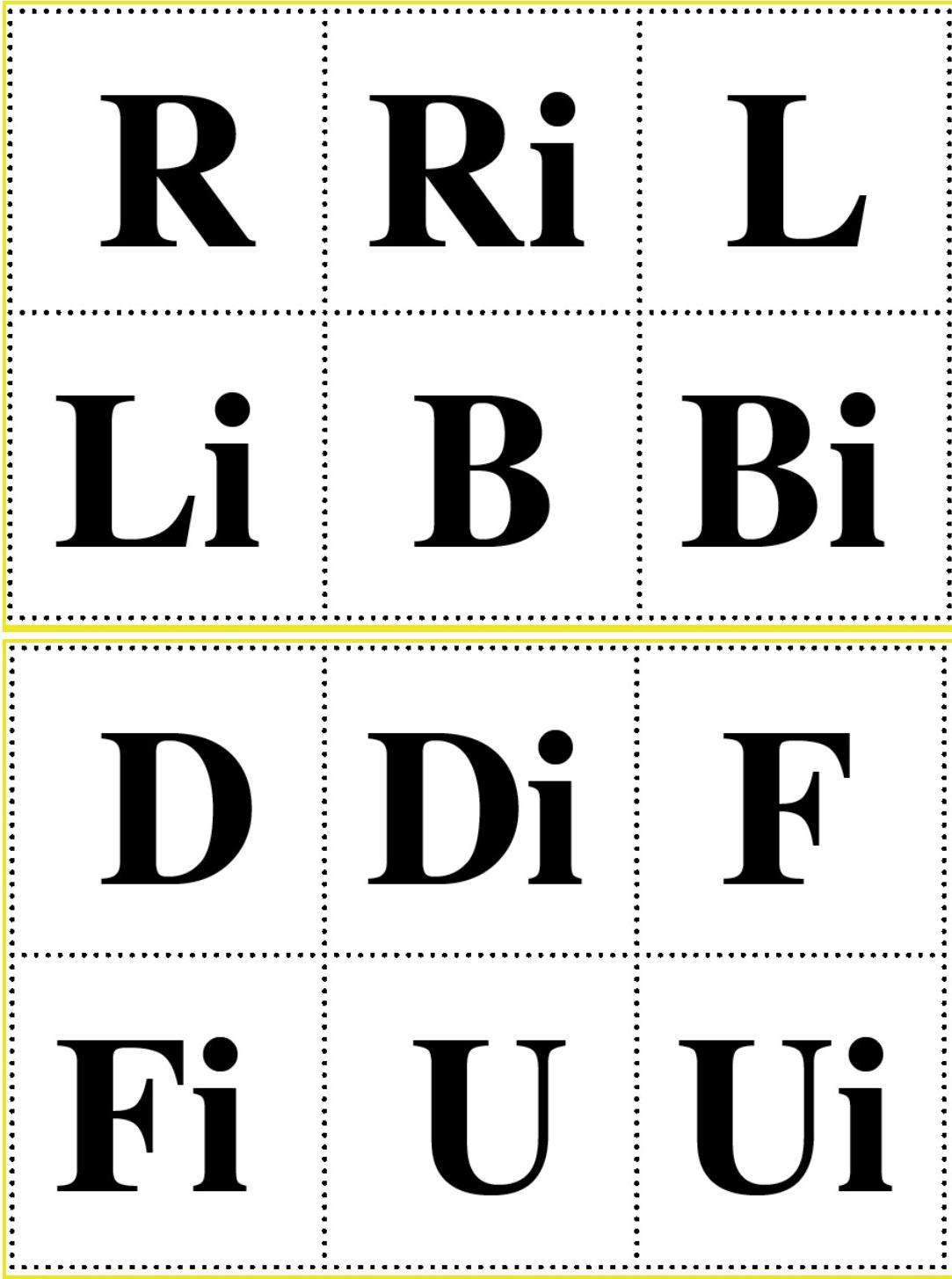
Ri is a counterclockwise turn of the RIGHT face.

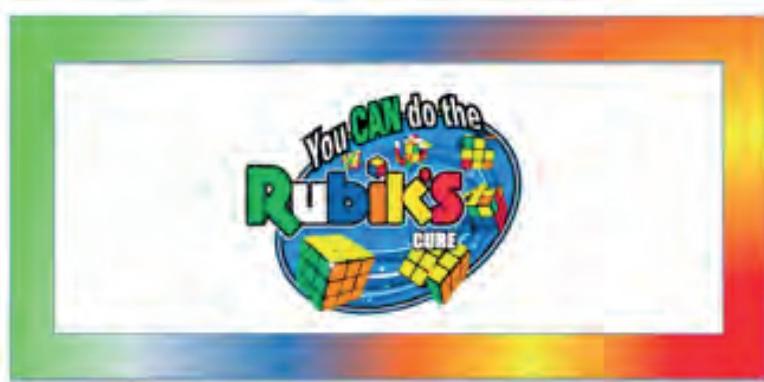


Memory Game

- Cut out each card.
- Place cards face down on the table.
- Take turns trying to match the image with the correct letter.





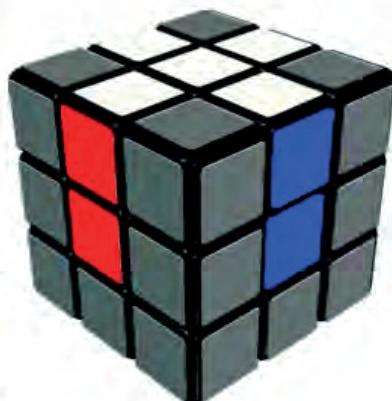


The **WHITE** Cross Lesson 2



GOAL: **The WHITE** Cross

The goal of this stage is to get the **WHITE** cross on the **UP** face with all the colored sides of the **WHITE** edges matching the center pieces.



CONTENT STANDARDS & SKILLS: LESSON 2

Grade	Common Core	NCTM
K-2	K.G.1 Names of shapes 1.G.1 Defining attributes of shapes 1.OA.B.3 Apply properties of operations as strategies	Geometry <ul style="list-style-type: none">• describe attributes and parts of two- and three-dimensional shapes• create mental images of geometric shapes• recognize shapes from different perspectives• relate ideas in geometry• recognize geometric shapes in the environment
3-5	3.OA.B.5 Apply properties of operations as strategies 4.OA.C.5 Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself. 4.G.1 Identify angles, perpendicular and parallel lines in two-dimensional figures	Number and Operations Geometry <ul style="list-style-type: none">• identify attributes of two- and three-dimensional objects; develop vocabulary to describe the attributes• describe objects and patterns• recognize geometric ideas and apply them in the classroom and everyday life
6-8	6.EE.A.3 Apply the properties of operations to generate equivalent expressions. 6.EE.A.4 Identify when two expressions are equivalent 7.EE.A.2 Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities in it are related. 8.G.A.1 Verify experimentally the properties of rotations, reflections, and translations.	Geometry <ul style="list-style-type: none">• precisely describe two- and three-dimensional objects using their attributes



The questions on these slides are meant to focus students on the characteristics of the Rubik's Cube. Depending on the grade level of your students, these questions may or may not be appropriate. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation.

Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Please modify your presentation to best meet the needs of your students.

Review: Slides 3 - 7

As you review the parts of the cube, emphasize the orientation (i.e. the FRONT face faces you) and how this differs from the color of the faces which is determined by the CENTER tile. The EDGE pieces will be the focus of the WHITE Cross so make sure students can readily identify those pieces.

Reviewing FACES

The flat (two-dimensional) square, on each surface of the cube.

How many faces does a cube have?

Up Face Down Face
Left Face Right Face
Front Face Back Face

Reviewing CENTER Pieces

Pieces with one color. Center pieces DO NOT MOVE.

How many center pieces are there?

Why are center pieces important?

BLUE Face WHITE Face
ORANGE Face

Reviewing EDGE Pieces

Pieces with two colors.

How many edge pieces are there on a Rubik's Cube?

Edge pieces are between the....

YELLOW/RED Edge Red/WHITE Edge

Reviewing CORNER Pieces

Pieces with 3 colors.

How many corner pieces are there?

Why do they have 3 colors?

GREEN/ORANGE/YELLOW Corner

Reviewing ¼ Turns

R	Ri	L	Li
D	Di	U	Ui
B	Bi	F	Fi

• Inverse means opposite.
• By using the inverse of a move, the move can be undone.

HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.

HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.



Lesson Content: Slides 8 - 21



SCRAMBLED CUBE
 25 Random $\frac{1}{4}$ Turns



This is just one example of a scramble.



In order to solve a Rubik's Cube, it must first be scrambled. A **scramble** is 25 random $\frac{1}{4}$ turns.

Have the students look at the sequence. Notice that there are no adjacent moves that are opposites of one another. (Ri never follows R.) Have students explain why this is true.



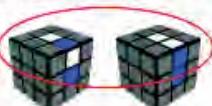
Layers and Faces
 When solving the cube, sometimes it's easier to talk about the layers.

Layers are three-dimensional (length, width and height), like layer cake.

TOP layer MIDDLE layer BOTTOM layer



The WHITE/BLUE edge pieces are in the TOP layer.



The difference between **layers** and **faces** can be confusing. The cake analogy may help. Layers of the cube are like layers of a cake. Faces on the cube are the frosting on the cake.

In this lesson, talking about the layers is an intermediary step to getting the WHITE tiles on the UP face. This will probably make more sense in the next series of slides.



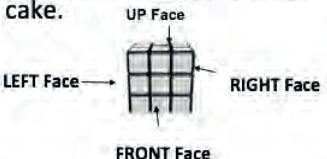
Layers and Faces
 When solving the cube, sometimes it's easier to talk about the layers.

The UP faces are covered with yellow.



Faces are the flat sides of the Cube. Faces are two-dimensional (length and width). Think of frosting that goes on all the sides of the cake.

UP Face LEFT Face FRONT Face RIGHT Face



Slides 11 - 13

Working with EDGES



Edge pieces are formed by 2 tiles on 2 adjacent faces. When making a design like the **WHITE** Cross, the location of the **WHITE** tile tells you which face to turn.

Where does the **WHITE** tile go when you make a turn?

Where does it go when you make a turn?

These slides are an opportunity to think purposefully about how the cube moves. The number of tiles on a piece determines the number of faces you can turn to move that piece. The focus here is on Edge pieces which are what you will need to make the **WHITE** Cross.

Where does the **WHITE** tile go when you make a F turn? The **WHITE** tile will go to the **BOTTOM** layer on the **FRONT** face.



When you make a Fi turn (on the original diagram), the **WHITE** tile will be on the **TOP** layer on the **FRONT** face.



Fi was a better move than F because the **WHITE** tile is on the **TOP** layer, but neither turn puts the **WHITE** tile on the **UP** face.

Working with EDGES



In this lesson, you will sometimes put the **WHITE** tile of the Edge piece on the **UP** face. The last 2 turns did not do that.

The **Non-WHITE** side of the Edge is on the **RIGHT** face. That's how you know to turn R or Ri.

Making an R turn will put the **WHITE** tile on the **UP** face, next to the **YELLOW** Center.

Have students determine how to get the:

- GREEN tile of the GREEN / RED Edge piece on the **UP** face. (F turn)
- RED tile of the GREEN / RED Edge piece on the **UP** face. (Li turn)
- YELLOW tile on the **BOTTOM** layer of the **LEFT** face (either Li F or L B) Another way of moving this tile is shown on slide 16.

The **WHITE Cross**



There are two parts to completing the **WHITE** Cross.

Part 1 makes a daisy on the **YELLOW** face. All the edge pieces surrounding the **YELLOW** center will be **WHITE**, just like a daisy.

Part 2 puts all the tiles for the **WHITE** cross on the **WHITE** Face. The EDGE tile colors on the **TOP** and **MIDDLE** layers will match the Centers.

There are many resources that state that making the daisy is intuitive. While many solvers find it fairly easy, slides 15 & 16 offer some tips for those who are getting stuck. If students are still struggling, go back to slides 11 & 12 to get a better feel for how the Edges move.



Slides 14 -16



First Goal:
To surround
the **YELLOW**
center with
WHITE Edge
pieces.



PART 1: Making the Daisy

- Hold the cube with the **YELLOW** center on the UP face.
- Find an Edge piece that has a **WHITE** tile.
- Turn the face without the **WHITE** tile until the **WHITE** tile is on the Up face.
- Repeat these steps until all 4 **WHITE** Edge tiles are on the UP face.

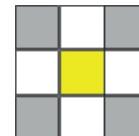


To make the Daisy, the **YELLOW** face must be the UP face. Now that you have the **YELLOW** Center, you need the **WHITE** petals.



Using what they learned about how Edge pieces move, students will locate the Edge pieces with **WHITE** tiles and put the **WHITE** tiles on the UP face surrounding the **YELLOW** Center.

View of UP face
when all **WHITE**
Edge tiles are in
place



First Goal:
To surround
the **YELLOW**
center with
WHITE Edge
pieces.



Troubleshooting the Daisy

Sometimes, when you place the Edge, you might "mess up" a **WHITE** tile that is already on the UP face..

You do this



and get this



The **WHITE / BLUE** Edge moved to the **RIGHT**!

To prevent this from happening, turn the TOP layer to get the **WHITE / BLUE** edge out of the way. In this case, make a or turn before making a turn.



HINT: Students may need to turn the TOP layer before moving an Edge piece so that they don't lose a **WHITE** tile that is in the correct position.



First Goal:
To surround
the **YELLOW**
center with
WHITE Edge
pieces.



Troubleshooting the Daisy

Sometimes, when you place the Edge, the **WHITE** tile is not on the UP face.

You do this



and get this



To "flip the Edge"- hold the cube so the Edge that needs to be flipped is on the RIGHT (R) face and make these turns:



Sometimes, the Edge piece is moved to the TOP layer but the **WHITE** tile is not on the UP face. This algorithm for "flipping an edge" is a handy one to know.

You might have students follow the algorithm for any Edge piece and then repeat the algorithm to see how the Edge piece returns to its original state. This may give them a better sense of what the algorithm does as well as extra practice executing the algorithm.



Slides 17 - 19

PART 1: Making the Daisy

When you have placed all 4 **WHITE** Edges on the UP face, the UP face will look like this:



First Goal:



To surround the **YELLOW** center with **WHITE** Edge pieces.



You are ready for Part 2!

At this point, the non-WHITE Edge pieces may not match their corresponding Centers. That's one of the goals of Part 2.

PART 2: Making the WHITE Cross



Goal:



To match the **EDGE** piece's color with the **CENTER**'s color on the **TOP** & **MIDDLE** layers.

- Pick one of the **WHITE** Edges.
- Turn the UP layer until the **non-WHITE** tile on the Edge matches the Center tile.



The daisy is on the UP face for Part 2. It doesn't matter which Edge you choose first. The important step is to match the non-WHITE tile of the Edge piece to its matching Center tile. In the example given, the ORANGE Edge tile is matched to its ORANGE Center by turning the UP face.

PART 2: Making the WHITE Cross



Goal:



To match the **EDGE** piece's color with the **CENTER**'s color on the **TOP** & **MIDDLE** layers.

Make 2 turns of that face (LEFT in this example). The **WHITE** tile will be on the DOWN face.



Repeat matching Edge to Center and making 2 turns for all 4 WHITE Edges.

Once the non-WHITE Edge is matched with its Center, 2 turns of that face (in the example, the ORANGE face) will move the WHITE tile to the DOWN face.

One at a time, match Edges to Centers and make 2 turns for each 4 the Edge pieces surrounding the YELLOW Center. Now, the petals of the daisy are being moved to the DOWN face.

HINT: Have students place the flat of their palm on the face with the matching Edge & Center. This will help them know which face to turn.



Slides 20 - 21

PART 2: Making the WHITE Cross

Turn the entire cube over so that the **WHITE** is now the UP face.

GOAL:
The **WHITE** Cross

The goal of this stage is to get the **WHITE** cross on the UP face with all the colored sides of the **WHITE** edges matching the center pieces.

Does your Rubik's Cube look like this?

Congratulations!
Congratulations!
Congratulations!
Congratulations!
Congratulations!
You have solved
The **WHITE Cross**

Review: Slides 22 - 24

These slides could be printed as a reference for students, perhaps in a learning center.

REVIEW

GOAL:
The **WHITE** Cross

The goal of this stage is to get the **WHITE** cross on the UP face with all the colored sides of the **WHITE** edges matching the center pieces.

- With the **YELLOW** face UP, make a daisy by putting the **WHITE** Edge tiles on the UP face.
- Turn the UP layer to match one **non-WHITE** Edge tile to its Center.

REVIEW

GOAL:
The **WHITE** Cross

The goal of this stage is to get the **WHITE** cross on the UP face with all the colored sides of the **WHITE** edges matching the center pieces.

- Make 2 turns to put the **WHITE** tile on the DOWN face.
- Turn the **WHITE** face UP to see the **WHITE** Cross!

REVIEW

GOAL:
The **WHITE** Cross

The goal of this stage is to get the **WHITE** cross on the UP face with all the colored sides of the **WHITE** edges matching the center pieces.

If the EDGE piece needs to be flipped, use this sequence:

Ri **U** **Fi** **Ui**

Make sure the EDGE piece you are trying to flip is on the **RIGHT** face.



Lesson Extension

How does this lesson apply to math?

The sequence **Ri, U, Fi, Ui**, is an **algorithm**.

A multiplication diagram showing 45 multiplied by 12. It has a grid with 4 rows and 12 columns, with a total sum of 540 at the bottom right. The numbers 4, 5, 1, and 2 are written above the grid.

- An algorithm is a set of rules or set of steps that we use to solve math problems.
- For example, when we multiply 45×12
 - First multiply 45 by 2.
 - Then multiply 45 by 10.
 - Last, add the two products together.

Math Connection: Slide 25

Any computational algorithm could be used here.



The slides on this page could be part of a class book, student journal, research project, or bulletin board.

Vocabulary: Slides 26 - 27

Vocabulary

Cube: 3 dimensional object with 6 square faces

Face: 2 dimensional surface or side of a cube

Center: The piece in the middle of a face. Face colors are the color of the center.

Corner: The piece where 3 faces meet

Vocabulary

Edge: The piece where 2 small tiles on different faces meet

Turn (move): a $\frac{1}{4}$ clockwise turn of a face of the Cube. A turn is 90° .

Layer: 3 dimensional slice of a Rubik's Cube

Inverse: an opposite action. The inverse of a move "undoes" the move.

Trivia: Slide 28

Question: If someone gave you a dollar for each of the possible combinations on a Rubik's® Cube, how much money would you have?

Answer: There are 43 quintillion combinations so you would have \$43 quintillion.
(43,252,003,274,489,856,000)

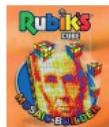
Reading large numbers and rounding to a specific place are great math connections here, too.



Did you know we have digital presentations that accompany this guide? Go to our website and select the **EDUCATORS** tab, then **Teaching to Solve**.

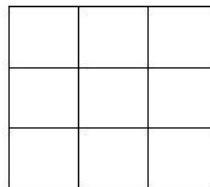
<https://www.youcandothecube.com/educators/>

You can also have your students practice using the skills for making the **WHITE** Cross with one of several lessons on our website that utilize the same skills to create other patterns. Go to our website and select the **EDUCATORS** tab, then choose **MATH** and **STEM** lessons.



Creating a Rubik's® Cube Mosaic: Making a Multi-colored Cross

Color a new cross or + pattern on the upper face grid below.
It doesn't matter what color the corner pieces are so leave them blank.



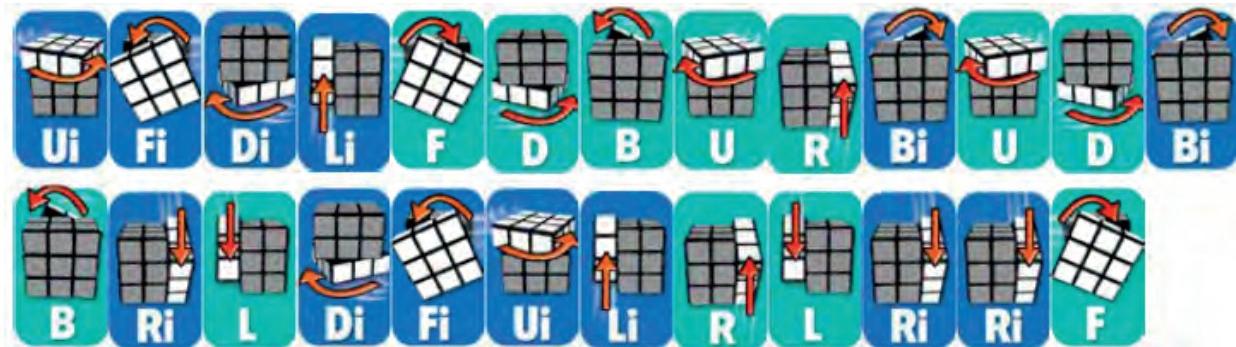
What turns should you make to create your pattern on the Rubik's® Cube?

Record your moves here.

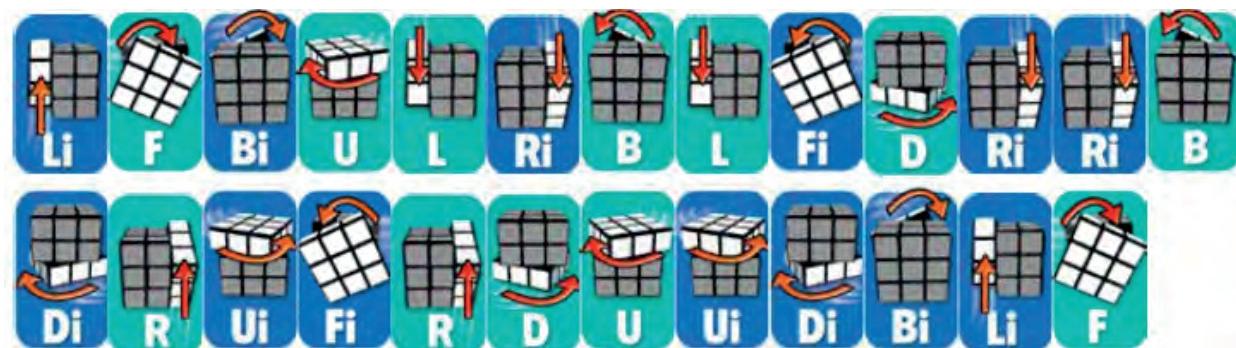
SCRAMBLING PRACTICE

Use the following sequences to practice scrambling your Rubik's Cube.

Sequence A - Will everyone's Cube look the same after this scramble? Why or why not?



Sequence B



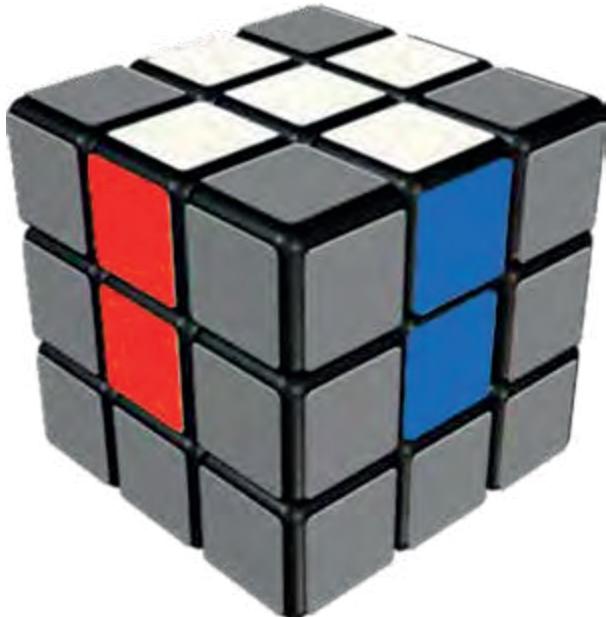
Sequence C - Record your own 25 turns to scramble a cube.

Any 25 turns of a Rubik's Cube is called a scramble. The goal is to mix the cube up as much as possible. Some scrambles might be better than others. What would be a bad scramble? Why?



How well do you know the cube?

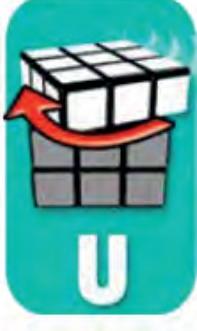
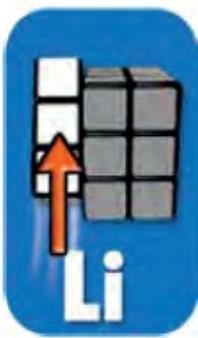
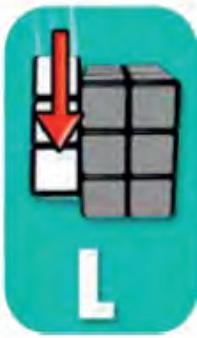
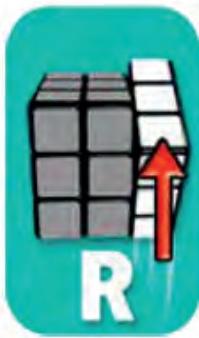
Here's a Rubik's Cube with a completed WHITE CROSS. The gray tiles could be any of the Rubik's Cube colors. It doesn't matter for this activity.

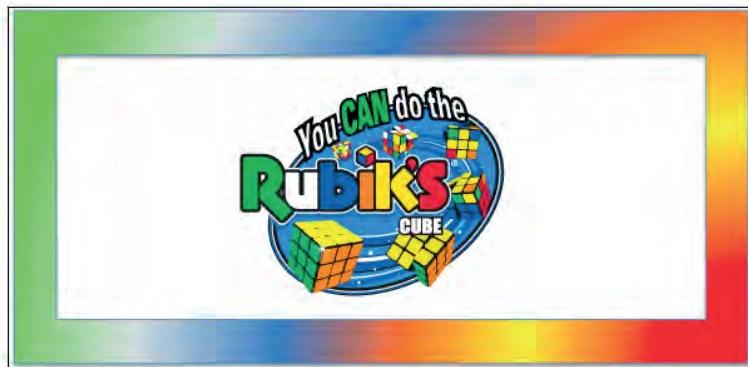


Color the cube below so that it shows what the hidden sides of the cube above look like.



QUARTER TURN REFERENCE SHEET





The **WHITE** Corners

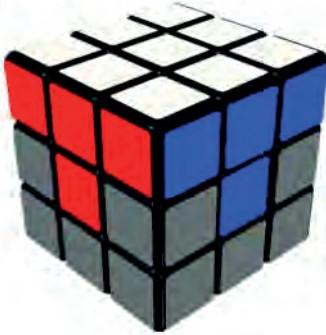
Lesson 3



Do you see the letter T on the RED, BLUE, ORANGE, and GREEN sides?

GOAL: The **WHITE** Corners

The goal of this stage is to get the **WHITE** corners on the **UP** face with the **TOP** layer of each face matching the center piece.





CONTENT STANDARDS & SKILLS: LESSON 3

Grade	Common Core	NCTM
K-2	<u>CCSS.MATH.CONTENT.K.G.B.4</u> Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).	Operations & Algebraic Thinking: <ul style="list-style-type: none"> Recognize, describe and extend patterns Analyze how patterns are generated Geometry: <ul style="list-style-type: none"> Use visualization, spatial reasoning & geometric modeling to solve problems.
3-5	<u>CCSS.MATH.CONTENT.1-3.G.A.</u> Reason with shapes and their attributes.	Number & Operations: <ul style="list-style-type: none"> Understand meanings of operations and how they relate to one another Algebra: <ul style="list-style-type: none"> Analyze change in various contexts Geometry: <ul style="list-style-type: none"> Predict and describe the results of sliding, flipping, & turning two-dimensional shapes
6-8	<u>CCSS.MATH.CONTENT.8.G.A.1</u> Verify experimentally the properties of rotations, reflections, and translations.	Number & Operations: <ul style="list-style-type: none"> Understand and use inverse relationships Geometry: <ul style="list-style-type: none"> Precisely describe two- and three-dimensional objects using their attributes Create & critique inductive & deductive arguments concerning geometric ideas & relationships



Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Please modify your presentation as best meets the needs of your students.

Many of the slides are animated so what you see in this guide may not appear all at once in the presentation.

Review: Slides 3 - 8

¼ Turns

R	Ri	L	Li
D	Di	U	Ui
B	Bi	F	Fi

- Inverse means opposite.
- By using the inverse of a move, the move can be undone.

Layers and Faces
When solving the Rubik's Cube, sometimes it's easier to talk about the layers.

Layers are three-dimensional (length, width and height), like layer cake.

TOP layer **MIDDLE layer** **BOTTOM layer**

Faces are the flat sides of the Cube. Faces are two-dimensional (length and width). Think of frosting that goes on all the sides of the cake.

UP Face LEFT Face FRONT Face RIGHT Face

SCRAMBLED CUBE
25 Random ¼ Turns
You have to scramble the cube to solve it!

REVIEW the WHITE Cross

GOAL: The **WHITE** Cross

- With the **YELLOW** face UP, make a daisy by putting the **WHITE** Edge tiles on the UP face.

The goal of this stage is to get the **WHITE** cross on the UP face with all the colored sides of the **WHITE** edges matching the center pieces.

- Turn the UP layer to match one **non-WHITE** Edge tile to its Center.

REVIEW the WHITE Cross

GOAL: The **WHITE** Cross

The goal of this stage is to get the **WHITE** cross on the UP face with all the colored sides of the **WHITE** edges matching the center pieces.

- Make 2 turns to put the **WHITE** tile on the DOWN face.

- Turn the **WHITE** face UP to see the **WHITE** Cross!

Vocabulary: ALGORITHM

An algorithm is a sequence of steps or a set of rules that we use to solve math problems.

REVIEW the WHITE Cross

Here is the **algorithm** to "flip" an Edge piece:



With each subsequent lesson, there is a greater need to check that the previous stage remains intact as the next stage is executed. Look for the reminders: **Check to see that you still have the cross!**

Lesson Content: Slides 9 - 18



Let's Start Solving!

In this stage, always hold the **WHITE** Cross as the **UP** face.



GOAL:
To get the **WHITE** corners in the correct positions.

Corner pieces have 3 tiles that are different colors. You will be looking for the Corners that have one **WHITE** tile and 2 other colors.

Have students use 3 fingers (thumb, index and middle fingers) to locate the CORNER. It does not matter which of the faces the tiles are on.



Get to the BOTTOM of it!

On the **BOTTOM** layer, find a Corner with a **WHITE** tile.



GOAL:
To get the **WHITE** corners in the correct positions.

Don't have a Corner with a **WHITE** tile on the bottom? No problem. The next slide will help you.



Get to the BOTTOM of it!

If a Corner with a **WHITE** tile is on the **UP** face, make U or Ui turns until that Corner is on the **RIGHT** face. Then follow this sequence:

GOAL:
To get the **WHITE** corners in the correct positions.



Check to see that you still have the **WHITE cross!**



Slides 12 - 15

Now that a Corner with a **WHITE** face is on the BOTTOM layer...

GOAL: To get the **WHITE** corners in the correct positions.

turn the DOWN (D) face until that corner is directly below its intended location.

In these examples, the RED-BLUE-WHITE Corner is between the RED face and the BLUE face.

How do you know where the intended position is? The non **WHITE** tiles should match the **CENTER** tiles of the faces the **CORNER** is between. It does not matter which of the **CORNER**'s tiles is on which face.

In this example, the **WHITE-BLUE-RED** Corner is between the **RED** and the **BLUE** faces.



Match your Cube to one of these 3 examples.

GOAL: To get the **WHITE** corners in the correct positions.

#1. If your Cube looks like this, with the **WHITE** tile on the FRONT face:

Make these turns to put the corner in the correct position.

Check to see that you still have the **WHITE cross!**

The location of the **WHITE** face on the corner tile determines the correct match. Make sure students are holding the Cube with the matching corner on the **RIGHT** face in the Bottom layer.

CAUTION: If the **WHITE** Cross has come undone, students will need to go back to Lesson 2/Stage 2 to recreate the **WHITE** Cross.

Match your Cube to one of these 3 examples.

GOAL: To get the **WHITE** corners in the correct positions.

#2. If your Cube looks like this, with the **WHITE** tile on the RIGHT face:

Make these turns to put the corner in the correct position.

Check to see that you still have the **WHITE cross!**

Match your Cube to one of these 3 examples.

GOAL: To get the **WHITE** corners in the correct positions.

#3. If your Cube looks like this, with the **WHITE** tile on the DOWN face:

Make these turns to put the corner in the correct position.

Check to see that you still have the **WHITE cross!**



Slides 16 - 18

REPEAT for each WHITE Corner!

GOAL:
To get the **WHITE** corners in the correct positions.

Check to see that you still have the **WHITE cross!**

These steps will be repeated to place the **WHITE** Corners on the **UP** face. This slide could be printed for student notebooks or a bulletin board along with slide 22. Slide 22 shows the 3 algorithms on one slide.

Examine your Rubik's Cube.

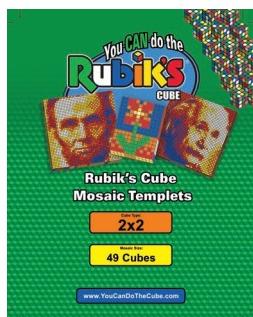
GOAL:
The **WHITE Corners**

The goal of this stage is to get the **WHITE** corners on the **UP** face with the **TOP** layer of each face matching the center piece.

Does your Rubik's Cube look like this?

Congratulations!
Congratulations!
Congratulations!
Congratulations!
Congratulations!
You have achieved
The **WHITE Corners**

Now that your students have solved the **WHITE** face, have them practice these skills by creating a mosaic with Rubik's Cubes. We have ready-made templates or you can create your own. Go to our website and select the **MOSAICS** tab to take advantage of all our resources. <https://www.youcandothecube.com/build-mosaics-with-rubiks-cubes/>





Math Connection: Slides 19 - 20

 **Math Connection**

PERMUTATION

A permutation is a different arrangement of something or all possible arrangements of something. Each move of a Rubik's Cube makes a new permutation of the Cube. How many permutations are there for a CORNER?



A permutation of 3 “objects” (WHITE, BLUE, RED tiles) would result in 6 arrangements.

3 • 2 • 1

Tile choices
for the first
position

Tile choices for
the second
position

One tile left for
the third
position

Why are there only 3 ways the Rubik's corner can be positioned? (The other color positions are not possible on a Rubik's Cube. For example, it is not possible to have the WHITE face FRONT, RED face RIGHT, and BLUE face DOWN in the lower RIGHT corner of a Rubik's Cube.)

 **Math Connection**

How does this lesson apply to math?

An **algorithm** is a sequential set of rules or steps.



There is a repeating pattern in the long division algorithm.

÷	Divide
×	Multiply
-	Subtract
✓	Check
↓	Bring down

Any computational algorithm could be used.



Review: Slides 21 - 22 These slides could be printed as a reference for students, perhaps in a learning center.



GOAL:

To get the **WHITE** corners in the correct positions.

This Algorithm Places the **WHITE Corners on the **BOTTOM** Layer**

- Hold the **WHITE** face as the **UP** face.
- Find a corner on the **TOP** layer and use a **U** or **Ui** turn to place it on the **RIGHT** face.
- Then follow the algorithm:





REVIEW

Follow the **algorithm** matching your Cube to place the **WHITE** tile of the corner on the **UP** face.

GOAL:

To get the **WHITE** corners in the correct positions.

Is the **WHITE** tile on the **FRONT** face? Then,



Is the **WHITE** tile on the **RIGHT** face? Then,



Is the **WHITE** tile on the **DOWNTILE**? Then,





Vocabulary: Slide 23


Vocabulary

Give some examples of **algorithms** you use.

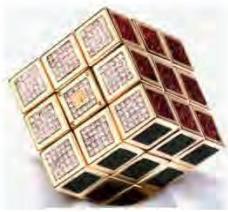
How would you explain how to find a **corner** on a Rubik's Cube?

Encourage students to have a broad definition of algorithm. What they do to get ready for school each morning could be an algorithm.

Use **vertex** in place of corner when appropriate.

Trivia: Slide 24



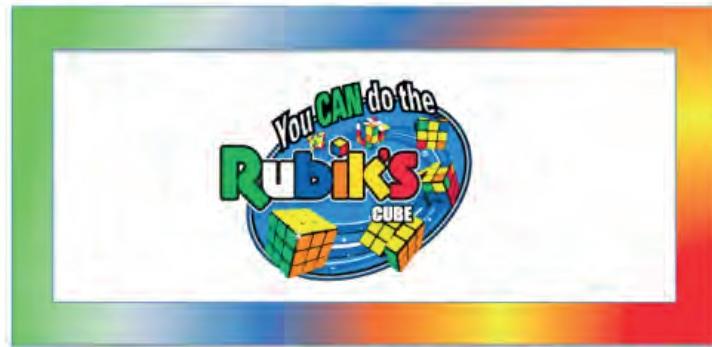


Question: Who produced the most expensive Rubik's Cube?
What was it called?

Answer:
The most expensive Rubik's Cube was the Masterpiece Cube, produced by Diamond Cutters International in 1995. The actual size, fully-functional cube features 185 carats of precious gems invisibly set in 18-karat gold. In its solved state, the cube features a different type of gem on each side—including 22.5 carats of amethyst, 34 carats of rubies and 34 carats of emeralds.

Answer:

The most expensive Rubik's Cube was the Masterpiece Cube, produced by Diamond Cutters International in 1995. The actual size, fully-functional cube features 185 carats of precious gems invisibly set in 18-karat gold. In its solved state, the cube features a different type of gem on each side—including 22.5 carats of amethyst, 34 carats of rubies and 34 carats of emeralds.



The MIDDLE Layer

Lesson 4



GOAL: The Middle Layer

The goal of this stage is to solve the Middle Layer while keeping the **WHITE** face intact.
(the **WHITE** cross and **WHITE** corners)



For this lesson, you will hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face. But first, let's review.

CONTENT STANDARDS & SKILLS: LESSON 4

Grade	Common Core	NCTM
K-2	<u>CCSS.MATH.CONTENT.1-3.G.A.</u> Reason with shapes and their attributes.	Algebra <ul style="list-style-type: none"> Recognize and describe patterns Geometry <ul style="list-style-type: none"> Use visualization, spatial reasoning & geometric modeling to solve problems
3-5	<u>CCSS.MATH.CONTENT.1-3.G.A.</u> Reason with shapes and their attributes. <u>CCSS.MATH.CONTENT.3.NF.A.1</u> Understand a fraction $1/b$ as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size $1/b$. <u>CCSS.MATH.CONTENT.3.NF.A.3</u> Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size. <u>CCSS.MATH.CONTENT.4.G.A.3</u> Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded along the line into matching parts. Identify line-symmetric figures and draw lines of symmetry.	Number & Operations <ul style="list-style-type: none"> Understand meanings of operations and how they relate to one another Algebra <ul style="list-style-type: none"> Analyze change in various contexts Geometry <ul style="list-style-type: none"> Predict and describe the results of sliding, flipping, and turning two-dimensional shapes
6-8	<u>CCSS.MATH.CONTENT.6.NS.C.5</u> Understand that positive and negative numbers are used together to describe quantities having opposite directions or values... <u>CCSS.MATH.CONTENT.7.NS.A.1.A</u> Describe situations in which opposite quantities combine to make 0. <u>CCSS.MATH.CONTENT.8.G.A.1</u> Verify experimentally the properties of rotations, reflections, and translations.	Number & Operations <ul style="list-style-type: none"> Understand and use inverse relationships Geometry <ul style="list-style-type: none"> Create and critique inductive and deductive arguments concerning geometric ideas and relationships

The MIDDLE Layer

Lesson 4



Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation. Please modify your presentation to best meet the needs of your students.

Review: Slides 3- 6

REVIEW – In solving the Middle layer, the UP face is very important.

UP Face Move:
a $\frac{1}{4}$ clockwise turn
of the up face

Think of closing a jar or
screwing in a lightbulb!

REVIEW

- Position the **WHITE** face as the **UP** face.
- Position a **WHITE** corner on the **BOTTOM** layer underneath its intended position.
- Use the algorithm as many times as needed until the corner is in the correct position.
- Repeat the steps for each **WHITE** corner until all four corners are in the correct positions.

Vocabulary

HORIZONTAL LINE

Horizontal is the word that describes when a line (or row) is parallel to the horizon. Horizontal lines go across. Rows are horizontal. The **layers** of the Cube are horizontal.

The **MIDDLE** layer is horizontal.

VERTICAL LINE

Vertical is the word that describes when a line is perpendicular to the horizon. Vertical lines go up/down. Columns are vertical. The **LEFT** and **RIGHT** sides of a Rubik's® Cube are vertical.

The MIDDLE Layer

Lesson 4



Content: Slides 7 - 11

Let's get started!

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

- Find an edge piece on the **TOP layer** that isn't **YELLOW** on the **UP** face or side.

- Match the **FRONT** face of the edge to the center piece of the same color by twisting the **TOP layer** until there is a vertical middle line of all one color on the **FRONT** face of the cube.

With the **YELLOW** center on the **UP** face, scan the **TOP** layer for an **EDGE** piece that has no **YELLOW** tiles. Once one **EDGE** piece has been located, match the color of the lateral face (not the **UP** face) of this tile with the color of the **CENTER** of the lateral face. If there are no **EDGE** pieces without **YELLOW** tiles, check **TROUBLESHOOTING** p. 6 of this guide.

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

ORANGE center
RED center

- Look at the **UP face** of the edge.
- Decide whether the edge needs to move to the **LEFT** or **RIGHT** by matching the **UP face** to the **center** tile.

Now look at the **UP** face of the tile you matched to a **CENTER**. The color of the **UP** tile will determine whether to follow the **LEFT** algorithm or the **RIGHT** algorithm. The algorithms for moving the cube to the **LEFT** or **RIGHT** are essentially the same. Because **LEFT** and **RIGHT** are inverses, the algorithms use inverse moves. Once students have seen the algorithm for moving the cube to the **ORANGE** or **LEFT** face, you may want to challenge them to provide the

algorithm for moving the cube to the **RED** or **RIGHT** face.

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

ORANGE center
If the **UP** face color belongs on the **LEFT**, do:

U
L
U
L
U
F
U
F

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

If the **UP** face color belongs on the **RIGHT**, do:
RED center

U
R
Ui
Ri
Ui
Fi
U
F

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The MIDDLE Layer

Lesson 4



Slides 12 - 14

That's all there is to it! Repeat these steps until the bottom 2 layers of the cube are solid colors.

- Find an **EDGE** piece on the **TOP layer/UP** face with no **YELLOW** tiles.
- Match the color of the “side” of the tile with a “side” face **CENTER** tile by twisting the **TOP** layer. You may want to remind students that this is a lightbulb or jar move.
- Look at the color of the **UP** face of the **EDGE** piece to decide whether the **EDGE** piece will move to the **LEFT** or the **RIGHT** face. Follow the appropriate algorithm.

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

You'll probably need to follow this process several times.

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

- Find an **EDGE** piece on the **TOP** layer that isn't **YELLOW** on the **UP** face or side.
- Match the **FRONT** face of the **EDGE** to the center piece of the same color by twisting the **UP** layer until there is a vertical middle line of all one color.

Remember, for this lesson, hold the cube so the **YELLOW** face is the **UP** face and the **WHITE** face is the **DOWN** face.

Goal: To move an edge piece on the top layer to its position in the MIDDLE layer

BLUE face → If edge piece belongs on **LEFT**, do:

GREEN face ← If edge piece belongs on **RIGHT**, do:

Repeat these algorithms until the bottom two layers are the same color on each of the sides of the cube.

Remember, hold the cube **YELLOW** UP and **WHITE** DOWN.

Make the middle column the same color by turning the **UP** face.

BLUE face → If EDGE belongs on left, do...

GREEN face ← If EDGE belongs on right, do...

The MIDDLE Layer

Lesson 4



Slides 15 - 18

Sometimes there are no **EDGE** pieces on the **TOP** layer with no **YELLOW** tiles. In this case, you will need to follow either the **LEFT** or the **RIGHT** algorithm once. This will “swap” a misplaced **EDGE** piece for the **EDGE** piece in the **TOP** layer. (see slide image) Now, there will be an **EDGE** piece on the **TOP** layer with no **YELLOW** tiles.

 **TROUBLESHOOTING**

If there are no more non-YELLOW edges to work with, use one of the algorithms to place a YELLOW edge on the RIGHT or LEFT face where there is an unsolved edge.



By moving a YELLOW edge to an unsolved place in the middle layer, the non-YELLOW edges will shift to give you the opportunity to work with a non-YELLOW edge.

 **TROUBLESHOOTING**

If you accidentally move an **EDGE** piece to the wrong place:

- Leave it there and continue working with the other **EDGE** pieces.
- Eventually, you will find the correct **EDGE** piece and place it in its correct place.
- The misplaced **EDGE** piece will be moved and available to move to its correct place.

 **Examine your Rubik's Cube**

GOAL:
The Middle Layer

The goal of this stage is to solve the Middle Layer while keeping the **WHITE** face intact (The **WHITE** cross and **WHITE** corners)



Does your Rubik's Cube look like this?



Congratulations!
Congratulations!
Congratulations!
Congratulations!
Congratulations!
You have achieved
The Middle Layer

Review: Slides 19 - 20

This slide could be printed as a reference for students, perhaps in a learning center.

 **REVIEW** - Repeat these steps until your cube looks like this:

Remember, hold the cube **YELLOW** UP and **WHITE** DOWN.

Make the middle column the same color by turning the **UP** face.

If edge piece belongs on **LEFT**, do... 
If edge piece belongs on **RIGHT**, do... 



 **Vocabulary**

Horizontal: Extending across from left to right. The layers of a Rubik's Cube are horizontal. 

Vertical: Extending from top to bottom. The **LEFT** and **RIGHT** sides of a Rubik's Cube are vertical. 

Inverse: An opposite action or position. Inverses “undo” an action. In the Rubik's Cube Solution Guide, an inverse move has the letter i after the turn. R and Ri are inverses. 

Algorithm: A series of steps.



Math Connections: Slides 21 - 25

There are several math connections for this lesson, a brief look at fractions and a longer look at inverses and solving equations.

 **Lesson Extension:** Fractions How does this lesson apply to math?

2/3

- There are three layers on a Rubik's Cube – **TOP, MIDDLE, BOTTOM**.
- When the **BOTTOM** and **MIDDLE** layers are complete, the cube is two-thirds solved.
- How many smaller cubes are in **one layer**?
- How many smaller cubes in **two layers**? ... in 3 layers?
- Make a fraction: # cubes in 2 layers
cubes in 3 layers
- * Simplify the fraction.

Fractions

- Explore fractions on a single face of the Cube. (i.e. What fraction of the face is RED?)
- Challenge students to make 2 faces of a cube $\frac{1}{3}$ RED.
- Some fractions can't be made on a Rubik's Cube. Which ones? Why?
- You can't make more than $\frac{1}{6}$ of the Cube RED because only one face of the Cube is RED. However, more than $\frac{1}{6}$ of a face could be RED. What is the greatest number of sides you can

consider to make a fraction where RED is greater than $\frac{1}{2}$? $\frac{1}{3}$?

 **Lesson Extension:** Inverses How does this lesson apply to math?

- To "undo" a move on the Rubik's Cube, you do the opposite of what was done.
- In math, the same idea applies.
- To "undo" addition, you subtract.
- The **inverse** of subtraction, is addition.

Try this "trick".

- Think of a number.
- Add 5 to your number.
- Subtract 5 from the new total.
- What number do you have? Why does the "trick" work?

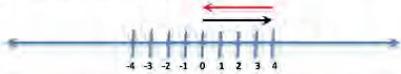


Inverses

- Inverses are opposites. What other opposites are there?
- Have students create other number tricks.

 **Lesson Extension:** Inverses How does this lesson apply to math?

- An **inverse** is an opposite.
- The opposite of a positive is a negative.
- When adding +4 and -4, the result is 0.



+4 and -4 are additive inverses.

- Zero is the identity element for addition because the additive inverses have a sum of 0. Does a Rubik's Cube have an identity element? What would it be?
- Identity elements are often included in the properties of a set. What other properties does a Rubik's Cube have?



Solving Equations

Lesson Extension:
Inverses

How does this lesson apply to math?

You can "undo" the move by using its inverse (doing the opposite). Each $\frac{1}{4}$ clockwise turn is "undone" by making a $\frac{1}{4}$ counterclockwise turn. For example, R₁ "undoes" R.

If you moved the UP face, edge piece to the right; you used the algorithm:

This is the inverse algorithm:

It makes the inverse moves in the reverse order. Notice the inverse algorithm moves the edge piece back to its initial location.

- Have students create a Rubik's sequence and then challenge a friend to write the inverse sequence.
- Have students highlight the inverses in a sequence.
- Mathematics has an order of operations. Does changing the order of the steps in the sequence change the results?

Lesson Extension:
Inverses

How does this lesson apply to math?

The Properties of Equality use inverses to solve equations.

$$\begin{array}{rcl} x + 5 & = & 11 \\ -5 & & -5 \\ \hline x & = & 6 \end{array}$$

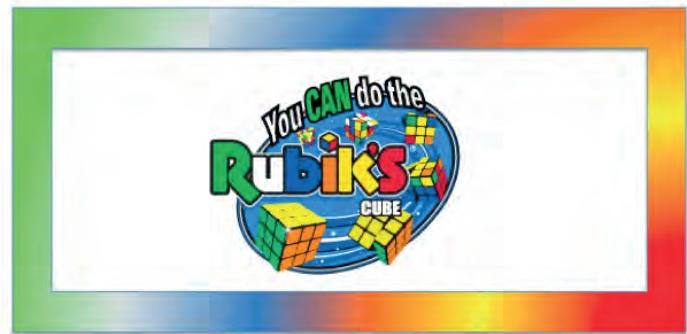
- To "undo" adding 5 to x, the opposite operation was used. The opposite of adding 5 is to subtract 5.
- By subtracting 5 from both sides of the equal sign, the equation was balanced and solved.
- This is the Subtraction Property of Equality.

- Challenge students to write a Rubik's Cube sequence in a way that mimics the equation solving process.

TRIVIA: Slide 26

Question: Who is the inventor of the Rubik's Cube?
Where is he from?

Answer: Erno Rubik (born 7/13/1944) is from Hungary.
The first cube was made of wooden blocks.



The **YELLOW** Face

Lesson 5



GOAL:
The **YELLOW Face**

The goal of this stage is to place all the **YELLOW** tiles on the **UP** face.



CONTENT STANDARDS & SKILLS: LESSON 5

Grade	Common Core	NCTM
K-2	<u>CCSS.MATH.CONTENT.1-3.G.A.</u> Reason with shapes and their attributes.	Algebra <ul style="list-style-type: none"> Recognize and describe patterns Geometry <ul style="list-style-type: none"> Use visualization, spatial reasoning & geometric modeling to solve problems
3-5	<u>CCSS.MATH.CONTENT.4.G.A.3</u> Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded along the line into matching parts. Identify line-symmetric figures and draw lines of symmetry.	Algebra <ul style="list-style-type: none"> Analyze change in various contexts Geometry <ul style="list-style-type: none"> Predict and describe the results of sliding, flipping, and turning two-dimensional shapes
6-8	<u>CCSS.MATH.CONTENT.8.G.A.1</u> Verify experimentally the properties of rotations, reflections, and translations.	Geometry <ul style="list-style-type: none"> Create and critique inductive and deductive arguments concerning geometric ideas and relationships



Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation. Please modify your presentation to best meet the needs of your students.

Review: Slides 3 - 5

REVIEW - The Middle Layer
Repeat these steps until your cube has 2 solid color layers like the cube on the right.
You'll probably need to follow this process several times.

Goal:

- Remember, hold the cube **YELLOW UP** and **WHITE DOWN**.
- Find an **EDGE** piece on the **TOP** layer that isn't **YELLOW** on the **UP** face or side.
- To move an edge piece on the top layer to its position in the MIDDLE layer
- Match the **FRONT** face of the **EDGE** to the center piece of the same color by twisting the **UP** layer until there is a vertical middle line of all one color.

REVIEW - Repeat these steps until your cube looks like this:

- Remember, hold the cube **YELLOW UP** and **WHITE DOWN**.

Make the middle column the same color by turning the **UP** face.

If cube belongs on **LEFT**, do... **BLUE** → **GREEN**

 If cube belongs on **RIGHT**, do... **U R U R U R U F U F F**

Vocabulary Review
How many do you know?

symmetry edge rotation
 corner face horizontal
 vertical layer

This is a static slide. Review terms as you see fit. Basic suggestions below:

Symmetry: a fold line where one half matches the other half exactly

Edge: where 2 faces meet

Rotation: a turn (90° on a Rubik's Cube)

Corner: where 3 faces meet

Face: the side of a cube

Horizontal: going across

Vertical: going up/down

Layer: a horizontal section (layer cake)

Lesson Content: Slides 6 - 22

 **Let's Get Started!**

For this lesson, hold the cube **YELLOW UP** and **WHITE DOWN**.

1st GOAL: To solve the **YELLOW** cross.

Just as we did with the **WHITE** face, we are going to start by making a cross on the **YELLOW** face. This time, we don't care if the sides of the EDGE pieces match the CENTER.



Does your **YELLOW** face have a **YELLOW** cross? If it does, you are ready for the **2nd goal**.



There are two parts to solving the **YELLOW** face. The first part is to solve for the **YELLOW** cross. The second part is to make the **UP** tile of the corners **YELLOW**. The corners will be matched to their correct **FACE** in Lesson 6, the final stage.

 If your Cube does **not** have a **YELLOW** cross on the **UP** face, then you need to match your cube to one of these.

GOAL: To solve the **YELLOW** cross.

Does your **YELLOW** face have ...

 **only the **YELLOW** center piece?**

 **a right angle shape at one of the corners?**

 **a single middle line horizontally or vertically?**

If you can't match one of these, the **MIDDLE** layer is not solved!

Just as with the **WHITE** cross, focus on the **EDGE pieces**. If there is not already a **YELLOW** cross, students will have a **YELLOW** "backwards L" in the upper left corner (middle image), a row of **YELLOW** tiles (right image), or neither (left image). Students should find the best match and hold the cube as shown.

has not been solved. The **MIDDLE** Layer must be solved to continue.

There will be 0, 2, or 4 **YELLOW** **EDGE** pieces. If there are 1 or 3 **YELLOW** **EDGE** pieces, then the **MIDDLE** Layer

Slides 8 - 11



Hold your cube to match one of these.

GOAL:
To solve
the
YELLOW
cross.

Follow the algorithm to make the **YELLOW** cross.
You may need to repeat the algorithm 2 or 3 times.
Remember to match your Rubik's Cube to one of
the three cube images above each time you begin
the algorithm.





For the stages of solving YELLOW face,
the orientation of the cube is very
important. Students should hold their
Rubik's Cubes to match one of the 3
examples.

HINT: Keeping the Cube on the table or
desk may help students attend to the
orientation of the cube which is an
important concept as they solve.



Imagery helps us to remember words and algorithms

To remember this algorithm, think about puppies!

GOAL:
To solve
the
YELLOW
cross.





YELLOW lab puppies have
FUR and say UiRiFi!

Orientation is key! Each time the
algorithm is completed, the cube must
be turned to match one of the 3
examples. Then, the algorithm is
repeated.



Examine your Rubik's Cube.

GOAL:
The YELLOW Cross

The goal of this stage is to
get the **YELLOW** cross
on the UP face.



Does your Rubik's Cube look like this?



GREAT! You did it!



Let's review some important vocabulary
that you'll need to understand to
complete the **YELLOW** face.





Slides 12 - 15

Vocabulary

LEFT/FRONT/UP

Corners can be named by their position as well as their color.

ORANGE/YELLOW/GREEN Corner

LEFT/FRONT/UP Corner

Vocabulary: Other Corner Names

RIGHT/BACK/UP

LEFT/BACK/UP

LEFT/BACK/DOWN

FRONT/RIGHT/UP

FRONT/RIGHT/DOWN

LEFT/FRONT/DOWN

Which corner is hidden?

The LEFT/FRONT/UP corner is the key to placing YELLOW corner tiles on the UP face to complete the YELLOW face. (The answer to “which corner is hidden?” is RIGHT/BACK/DOWN.)

Here we go!

Make sure the **YELLOW** face is the UP face.

2nd GOAL:

To put the **YELLOW** tiles on the **UP** face.

- Just as we did with the **YELLOW** cross, we are going to look for matching images to help us get to the next step.
- We will focus on the **LEFT/FRONT/UP** corner.

The next 4 slides show the matching positions. Each time you repeat the algorithm for the corners, students will need to match the placement of the YELLOW tile on the LEFT/FRONT/UP corner, depending on the number of YELLOW tiles already on the corners of the UP face.

GOAL:

To get the **YELLOW** tiles on the **UP** face.

Match your Rubik's Cube to one of the Cubes **on the this slide or the next 2 slides.**
Pay attention to the corners!

No YELLOW corners on the **UP** face

Hold the Cube so the **LEFT/FRONT/UP** corner has a **YELLOW** tile on the **LEFT** face.

If there are **no** YELLOW corner tiles, turn the entire cube (the whole cube) until the LEFT/FRONT/UP corner has a YELLOW tile on the LEFT.

Slides 16 - 18

 Does this Rubik's Cube match yours?
Pay attention to the corners!

One **YELLOW** corner is on the **UP** face

GOAL:

To get the **YELLOW** tiles on the **UP** face.

 See the fish diving?

Hold the Cube so the **LEFT/FRONT/UP** corner has a **YELLOW** tile on the **UP** face. It doesn't matter what colors are on the other two faces of the corner.

If there is **one** **YELLOW** corner tile, turn the entire cube (the whole cube) until there are no **YELLOW** tiles on any of the lateral sides of the **LEFT/FRONT/UP** corner.

HINT: Make the "fish" dive!

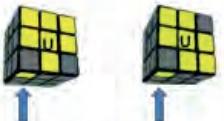


 Does this example match your Rubik's Cube?
Pay attention to the corners!

Any **two** **YELLOW** corners are on the **UP** face

GOAL:

To get the **YELLOW** tiles on the **UP** face.



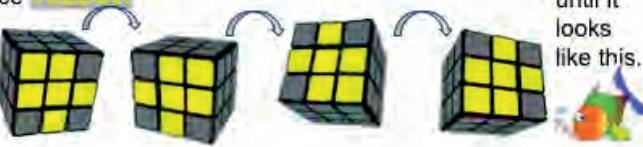
Hold the Cube so the **LEFT/FRONT/UP** corner has a **YELLOW** tile on the **FRONT** face.

If there are **two** **YELLOW** corner tiles, turn the entire cube (the whole cube) until the **FRONT** of the **LEFT/FRONT/UP** corner is **YELLOW**. It doesn't matter where the 2 corner **YELLOW** tiles are.

HINT: Try this saying: **If there's two, towards you.**

(If there are 2 **YELLOW** corners, then a **YELLOW** tile on the **LEFT/FRONT/UP** corner faces you.)

 **Troubleshooting**
If your Rubik's Cube does not match one of the three options exactly, you might need to rotate your Cube (turn the whole cube without twisting any layers) so the **LEFT/FRONT/UP** corner has a **YELLOW** piece on the **LEFT**, **UP** or **FRONT** face.

Turn the **WHOLE** Cube but remember to keep the **UP** face **YELLOW**
 until it looks like this.

This slide illustrates turning the whole cube to find the best match.

Note the image on the left is the starting position.

Slides 19 - 22

GOAL:
To get the **YELLOW** tiles on the UP face.

Once your Rubik's Cube matches one of these:

use this algorithm.

For the stages of solving YELLOW face, the orientation of the Rubik's Cube is very important. Students should hold their Cubes to match one of the 3 examples.

HINT: Keeping the Cube on the table or desk may help students attend to the orientation of the Cube, which is an important concept as they solve.

GOAL:
To get the **YELLOW** tiles on the UP face.

Match your Rubik's Cube to one of these again.
Pay attention to the corners!

Re-match and repeat the algorithm until the **YELLOW** tiles are all on the **UP** face.

Orientation is key! Each time the algorithm is completed, the Cube must be turned to match one of the 3 examples. Then, the algorithm is repeated.

When the **YELLOW** face is complete, the lateral faces of the corners may not match their corresponding CENTER tiles. This last step will be accomplished in the next lesson.

GOAL:
The YELLOW FACE

The goal of this stage is to place the **YELLOW** tiles on the **UP** face.

Examine your Rubik's Cube.

Does your Rubik's Cube look like this?

Congratulations!
Congratulations!
Congratulations!
Congratulations!
Congratulations!
You have achieved
The **YELLOW Face**

Math Connections - Slides 23 - 26

Generally, transformations involve moving an object in a specific way. After the transformation is complete, the result will be congruent to the original object. This may contradict students' non-math understanding of transformations such as the Transformer series of toys and cartoon characters.



Lesson Extension: How does this lesson apply to math?

The **YELLOW** cross has both line and rotational symmetry.

Line symmetry is when an image can be folded in half and both halves match exactly. A shape can have more than one line of symmetry.

Rotational symmetry is when an image is turned and matches the original image. The **YELLOW** cross has rotational symmetry at 90° , 180° , and 270° .





Students may be familiar with line symmetry. Younger students could be challenged to find all the lines of symmetry on a single face. Explore how color influences lines of symmetry.

Older students may more easily grasp the concept of rotational symmetry by turning a Rubik's Cube. Challenge students to create other patterns on a face of a cube that have rotational symmetry. This may work well with partners (or with 2 cubes) so that one Cube remains in the same position while the second Cube is turned and

compared to the first. Place the Rubik's Cube on a paper plate to turn it easily.



Lesson Extension: How does this lesson apply to math?

Transformations

Matching the images on the **YELLOW** face are the beginning steps to learning about translation, rotation, and reflection.

A **translation** is when the image slides to a new place but does not change.

- With any unsolved face up on your desk, slide the cube to the right. Then left. Then straight towards you. Then straight away from you, and then diagonally.
- If does not matter which way you slide the cube, the image on the face does not change. Only the location of the cube changes.



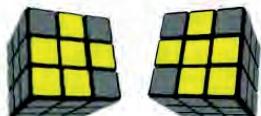
A translation or slide is a movement of an object along a line. This may seem obvious and the point can easily be lost. Have students think about where translations are seen in their world. Fabric and wallpaper with repeating patterns can be examples of translations. What would happen if the creator "stamped" a design without paying attention to whether or not the stamps were placed along a line? (The fabric or wallpaper may look crooked.) Students might try this using stamps or stickers to get a better sense of the concept of translation. Use a ruler as the slide

line, the line along which the Rubik's Cube will move.



Lesson Extension: How does this lesson Transformations apply to math?

Matching the images on the **YELLOW** face is the beginning step to learning about translation, rotation, and reflection.



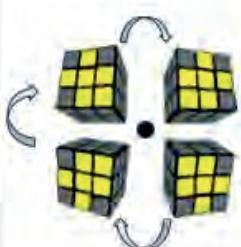
A reflection is when the image of one side looks the opposite of the other, like looking in a mirror.

- Try to find another student whose Rubik's Cube is a mirror image of your own.
- Draw the mirror image of your Rubik's Cube.



Lesson Extension: How does this lesson Transformations apply to math?

A rotation is when the cube or face turns around a point. Rotations are measured in degrees. A full rotation, back to the original position, would be 360 degrees.



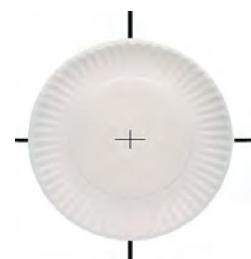
- You can try this by placing your Rubik's Cube on a piece of paper with any unsolved face up.
- Choose a corner and mark the spot on the paper with a dot.
- Keep the corner of the Cube the same distance from the dot as you move or rotate it around the dot.

In a reflection, the image of the object is flipped over a line.

Placing a small mirror or a piece of plexiglass between 2 cubes may help students see the line of reflection.

Rotations are turns of an object around a point, the center of rotation. Place the Rubik's Cube on a paper plate or Lazy Susan and mark the center of rotation. Place a finger on the center as the plate is turned.

The plate could be placed on top of a larger piece of paper with an xy axis so that students could see the 90° turns.



Review: Slides 27 - 29

These slides could be printed as a reference for students, perhaps in a learning center.

REVIEW THE **YELLOW CROSS.**

Hold your cube to match one of these.

1st GOAL:

To solve the **YELLOW** cross.

Follow the algorithm to make the **YELLOW** cross. You may need to repeat the algorithm 2 or 3 times, remember to match the top of your Cube each time.

F **U** **R** **Ui** **Ri** **Fi**

REVIEWING the **YELLOW Face**

Count the number of **YELLOW** corner tiles on the UP face.

2nd GOAL: Match your Rubik's Cube to one of these positions.

To get the **YELLOW** corners on the UP face.

No **YELLOW** corners? The left tile of LEFT corner must be **YELLOW**.

Top U Face View

ONE **YELLOW** corner? This corner must be in the UP LEFT FRONT.

TWO **YELLOW** corners? The front tile of LEFT corner must be **YELLOW**.

REVIEWING the **YELLOW Face**

Match your Rubik's Cube to one of these. Pay attention to the corners!

Any 2 corners are **YELLOW**

2nd GOAL:

To get the **YELLOW** corners on the UP face.

Follow the algorithm.

R **U** **Ri** **U** **R** **U** **U** **Ri**

Re-match and repeat the algorithm until all the **YELLOW** corners are on the **UP** face.

TRIVIA: Slide 30-31

**Question: How big was the largest Rubik's Cube?
Who built it?**

Answer: The largest Rubik's Cube was built by Tony Fisher of the UK in 2016. It is fully functional and stands 1.5 meters tall x 1.5 meters long x 1.5 meters wide (which is about 5'2" on each side).



Lesson 6

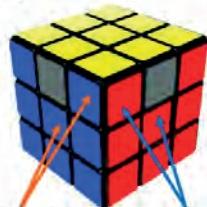


Positioning the **YELLOW** Corners & Edges



1st GOAL: The **YELLOW** Corners

The goal of this stage is to get the **YELLOW** corners positioned correctly.



The **BLUE** face of the corner matches the **BLUE** center.

The **RED** face of the corner matches the **RED** center.



Congratulations! The **YELLOW** corners are in the correct positions.



Now, let's position the edges and solve the cube!!

2nd GOAL: The **YELLOW** Edges

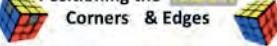
The goal of this stage is to solve the **YELLOW** edges - the final step to solving the Rubik's Cube.



CONTENT STANDARDS & SKILLS: LESSON 6

Grade	Common Core	NCTM
K-2	<u>CCSS.MATH.CONTENT.K.G.B.4</u> Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).	Algebra <ul style="list-style-type: none"> Recognize and describe patterns Geometry <ul style="list-style-type: none"> Use visualization, spatial reasoning and geometric modeling to solve problems
3-5	<u>CCSS.MATH.CONTENT.5.G.B.3</u> Understand that attributes belonging to a category of two- dimensional figures also belong to all subcategories of that category.	Algebra <ul style="list-style-type: none"> Analyze change in various contexts Geometry <ul style="list-style-type: none"> Predict and describe the results of sliding, flipping, and turning two-dimensional shapes
6-8	<u>CCSS.MATH.CONTENT.7.G.B.5</u> Use facts about supplementary, complementary, vertical, and adjacent angles in a multi-step problem to write and solve simple equations for an unknown angle in a figure. <u>CCSS.MATH.CONTENT.8.G.A.1</u> Verify experimentally the properties of rotations, reflections, and translations.	Algebra <ul style="list-style-type: none"> Represent and analyze mathematical situations and structures using symbolic language Geometry <ul style="list-style-type: none"> Create and critique inductive and deductive arguments concerning geometric ideas and relationships

Lesson 6
Positioning the **YELLOW**
Corners & Edges



Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation. Please modify your presentation to best meet the needs of your students.

Review: Slides 2 - 4

REVIEW THE **YELLOW CROSS.**

Hold your cube to match one of these.

1st GOAL:



Follow the algorithm to make the **YELLOW** cross. You may need to repeat the algorithm 2 or 3 times, remember to match the top your cube each time.

To solve the **YELLOW** cross.



REVIEWING the **YELLOW Face**

Count the number of **YELLOW** corner tiles on the UP face.

Match your cube to one of these positions.

2nd GOAL:



to get the **YELLOW** face on the UP face.



No **YELLOW** corners? The left tile of LEFT corner must be **YELLOW**.



ONE **YELLOW** corner? This corner cube must be in the UP LEFT FRONT.



TWO **YELLOW** corners? The front tile of LEFT corner must be **YELLOW**.

REVIEWING the **YELLOW Face**

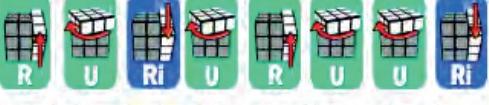
Match your cube to one of these. Pay attention to the corners!

GOAL:



Any 2 corners are **YELLOW**.

To get the **YELLOW** tiles on the UP face



Follow the algorithm.

Re-match and repeat the algorithm until all the **YELLOW** corners are in their correct position.

Vocabulary: Slides 6 - 8

 You're almost there!

Let's review some important vocabulary that you'll need to understand to finish solving the Rubik's Cube.



Vocabulary

ADJACENT neighboring, next door A is adjacent to C and B .		DIAGONAL Vertex A is not connected to vertex D so they are not adjacent corners. (Note that the terms vertex and corner are used interchangeably.) Vertex C is adjacent to A and D .
---	--	---

Which corners are adjacent to C?

Adjacent corners or vertices are connected by the sides of the polygon. Vertex A is connected to vertex B and vertex C by the edges. Therefore, corner A is adjacent to corners B and C. Vertex A is not connected to vertex D so they are not adjacent corners. (Note that the terms vertex and corner are used interchangeably.) Vertex C is adjacent to A and D.



Vocabulary

ADJACENT neighboring, next door A is adjacent to C and B .		DIAGONAL Two non-adjacent corners of a face. A and D are diagonal.
---	---	---

Name other diagonal corners.

Diagonal vertices are not connected by the sides of the polygon. Vertex A is diagonal to vertex D. B and C are also diagonal vertices.

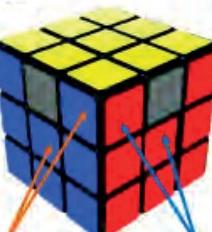
It is important that students begin to develop the understanding that diagonals are not "slanted" lines. A and D will always be diagonal vertices. If the cube in this slide is rotated 45°, the line segment connecting them will be horizontal, not slanted.

Lesson Content: Slides 8 - 23



1st GOAL:
The YELLOW Corners

The goal of this stage is to get the **YELLOW** corners positioned correctly.



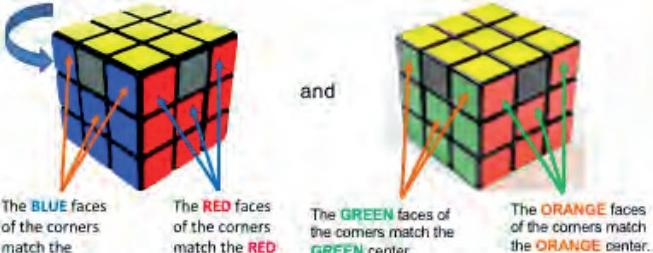
The **BLUE** face of the corner matches the **BLUE** center.
The **RED** face of the corner matches the **RED** center.

This step differs from previous steps where the **EDGES** were aligned with the **CENTER** before the **CORNERS**. With the **YELLOW** face, the **CORNERS** are matched to their corresponding **CENTERS** first.



Make sure the **YELLOW** face is the **UP** face.
Twist the **TOP** layer to see if the **YELLOW** corners can be placed in the correct position, matching their **RED**, **BLUE**, **ORANGE**, or **GREEN** centers.

Lesson Focus



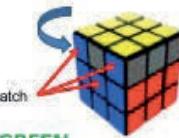
The **BLUE** faces of the corners match the **BLUE** center.
The **RED** faces of the corners match the **RED** center.
The **GREEN** faces of the corners match the **GREEN** center.
The **ORANGE** faces of the corners match the **ORANGE** center.

Some of the **CORNERS** can easily be aligned with their corresponding **CENTERS** by twisting the **TOP** layer.



GOAL:
The **YELLOW Corners**

If the adjacent corners match:
Twist the **TOP** layer to see if any 2 adjacent corners match the center piece color. It might look like this or maybe you have matching **RED** or **GREEN** or **ORANGE** adjacent corners.



The goal of this stage is to get the **YELLOW** corners positioned correctly.

Now hold the cube so the matching adjacent corners (A & B) are on the **BACK** face.



First, check for adjacent corners that match their corresponding **CENTERS**. These adjacent corners will match the same **CENTER** tile. In the example, both **CORNERS** match the **BLUE** **CENTER**.

If there is a pair of matching adjacent **CORNERS**, hold the cube so they are away from you, on the **BACK** face.

Slides 11 - 13

If two diagonal corners that match their centers:

Twist the **TOP** layer to see if one set of diagonal corners match the center piece colors.

For example, twist the **TOP** layer so **BLUE** corner matches **BLUE** center and **RED** corner matches **RED** center.

The goal of this stage is to get the **YELLOW** corners positioned correctly.

Either A & D have faces that match their centers or B & C have faces that match their centers.

Diagonal CORNERS that match their corresponding CENTERS will match different colored CENTERS. In this slide, the diagonal CORNERS match the **BLUE** and **RED** CENTERS.

It does not matter which of the matching CORNERS is on the BACK face.

Now that you have either adjacent or diagonal corners lined up, follow this algorithm.

Whether CORNERS aligned or not, this algorithm may need to be repeated several times before the cube is solved.

HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.

If you have not reached the goal, hold the cube so the matching adjacent corners are on the **BACK** face. Repeat the algorithm.

Troubleshooting

Be sure to check for adjacent or diagonal corners after every completion of the algorithm.

This is especially important when attempting longer algorithms the first time. The excitement of nearly solving can be dashed when missteps scramble the cube.

And remember to hold the cube so the matching adjacent corners (A & B) are on the **BACK** face.

Slides 14 - 17



Examine your Rubik's Cube.

GOAL:
The YELLOW Corners

The goal of this stage is to get the **YELLOW** corners positioned correctly.



Does your Rubik's Cube look like this?



Congratulations! The YELLOW corners are in the correct positions.



Now, let's position the edges and solve the Rubik's Cube!

2nd GOAL: The YELLOW Edges

The goal of this stage is to solve the **YELLOW** edges - the final step to solving the Rubik's Cube.





With **YELLOW** as the **UP** face, get ready to solve.

GOAL:
Solve the **YELLOW** edges

- Make sure ALL the corners are in the correct position. The lateral faces of the **YELLOW** corners will match the centers.
- See if there is lateral face that is completely solved. The color of the solved face on your cube might be different than this example.





There may not be a lateral face that is completely solved.



GOAL:
Solve the **YELLOW** edges.

- Hold the cube so the solved face is the **BACK** face. In this example, **GREEN** would be the **BACK** face.
- If you DO NOT have any solved faces, it doesn't matter which face is the **BACK**.





If there is a solved face, hold the Cube so the solved face is away from you, on the **BACK** face.

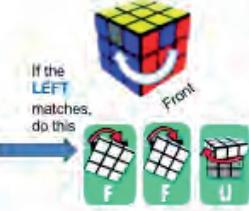
HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.

This is especially important when attempting longer algorithms the first time. The excitement of nearly solving can be dashed when missteps scramble the cube. It's worth mentioning again!

Slides 18 - 20

 Look at the yellow edge piece on the FRONT face. Does the lateral face color match the LEFT face or the RIGHT face?

GOAL:
Solve the **YELLOW** edges.

If the **LEFT** matches, do this 

If the **RIGHT** matches, do this 

You'll need to remember whether you turned **LEFT** or **RIGHT** a little later.

This can be a stumbling point for some solvers. If you turn the wrong way, you get stuck in an endless loop of repeating this step. And that's really frustrating!

HINT: Match the arrows! If the EDGE tile matches the LEFT face, the third turn (slide 18) and tenth turn (slide 20) will be an UP turn to the LEFT. If the EDGE tile matches the RIGHT face, the third turn (slide 18) and tenth turn (slide 20) will be an UP turn to the RIGHT.

 It doesn't matter for this part whether the lateral face color matches the LEFT face or the RIGHT face.

GOAL:
Solve the **YELLOW** edges.

Make these turns next: 

 When you started this step, did you turn to match the LEFT face or the RIGHT face?

GOAL:
Solve the **YELLOW** edges.

If you turned **LEFT**, then do this 

If you turned **RIGHT**, then do this 

The last 2 turns in this algorithm are: 

The last 2 turns are the same whether the cube was turned to the LEFT or the RIGHT earlier.

Slides 21 - 23

Repeat these steps until the Rubik's Cube is solved!

- Hold the Cube with a solved face on the **BACK**.
- Look at the yellow edge piece on the **FRONT** face.

Does the lateral face color match the **LEFT** face?

GOAL:
Solve the **YELLOW** edges.

If the **LEFT** matches, do this →

or the **RIGHT** face?

If the **RIGHT** matches, do this →

After completing the algorithm, stop to check which side the **EDGE** tile matches.

This algorithm matches all the tiles in the top row of the lateral faces. Sometimes the top row tiles will all be the same color but not match the **CENTER** tile. A twist (or 2) of the **TOP** layer should make everything right.

You CAN do the Rubik's Cube!

Examine your Rubik's Cube.
You might need to twist the **TOP** layer to match the sides.

2nd GOAL:
The YELLOW Edges

The goal of this stage is to solve the **YELLOW** edges - the final step to solving the Rubik's Cube.

Does your Rubik's Cube look like this?

You CAN do the Rubik's Cube!

Congratulations!
Congratulations!
Congratulations!
Congratulations!
Congratulations!
Congratulations!
You have solved the Rubik's Cube!

Math Connections: Slides 24 - 25

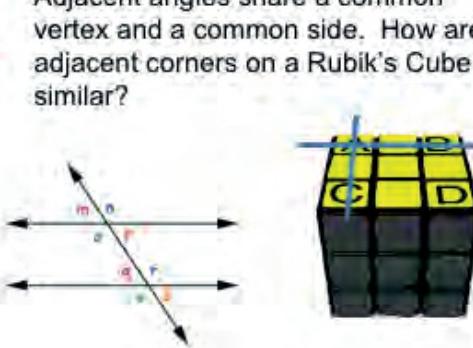


Lesson Extension

How does this lesson apply to math?

Adjacent angles share a common vertex and a common side. How are adjacent corners on a Rubik's Cube similar?

How are they different?



Similarities: One could make the case that the corners adjacent to A are on the sides of angle A. A is the vertex formed by the lines connecting the adjacent corners; point A is the vertex of the adjacent angles. The intersecting segments that connect the adjacent corners form adjacent (and vertical) angles.

Difference: Adjacent angles share a common vertex and a common side. Angle DAJ and angle JAT are adjacent because they share vertex A and have ray AJ as a common side. Pairs of adjacent corners on a cube have a common vertex but do not share a common side.



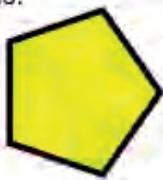
Lesson Extension

How does this lesson apply to math?

Diagonals are line segments that connect non-adjacent corners or vertices.

As you've seen in this lesson, a 4 sided polygon has two diagonals.

How many diagonals are there in a 5 sided polygon?



As stated earlier in this lesson, it is important that students begin to develop the understanding that diagonals are not "slanted" lines. One might use this opportunity to explore diagonals in other polygons. Triangles have no diagonals. In polygons with more than 4 sides, there is more than one diagonal from any given vertex. Older students may find the pattern in the total number of diagonals in a polygon and generalize that pattern algebraically.

Review: Slides 26 - 28

These slides could be printed as a reference for students, perhaps in a learning center.

REVIEW

To get the **YELLOW** corners positioned correctly

With **YELLOW** as the **UP** face, get ready to solve by holding your cube in one of these positions.

- Twist the **TOP** layer until two adjacent corners (shown as AB or CD) match with the center piece color.
- Hold the cube so that the matching adjacent corners are on the **BACK** face.
- If you do not have two adjacent corners matching on the **TOP** layer:
- Twist the **TOP** layer until one set of diagonal corners (shown as AD or BC) match with the center piece color.

REVIEW

To get the **YELLOW** Corners positioned correctly

Now, follow the algorithm :

Repeat the algorithm until all the **YELLOW** corners are in the correct positions.

Review

Hold the cube with **YELLOW** as the **UP** face.

- If you have a lateral face that is completely solved, hold the cube with the solved face as the **BACK** face.
- Decide whether the edge pieces should move clockwise along the **TOP** layer to solve the cube

If the edge piece on the **TOP** layer should move clockwise:

or counter-clockwise to solve the cube.

If the edge piece on the **TOP** layer should move counter-clockwise:

TRIVIA: Slide 29



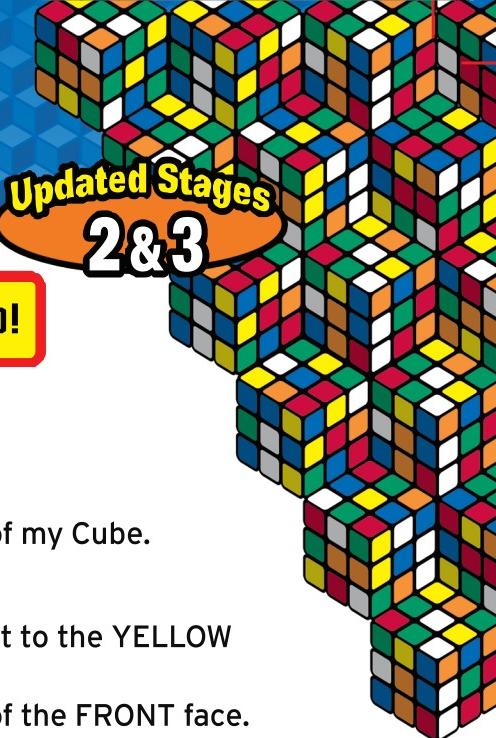
Question: About how many Rubik's Cubes have been sold worldwide?

**Answer: More than 400 million and counting!
In 2017, an estimated 5% of the world population could
solve a Rubik's Cube. And now, you're one of them!**

The reported percentage of the world population that can solve a Rubik's Cube in 2017 varied from 3% to 6%. Some students may be challenged to figure out how many new solvers it would take to increase the percentage 1%.



CHECK LIST FOR SOLVING THE RUBIK'S CUBE



Updated Stages
2 & 3

CHECK EACH BOX AS YOU MOVE FORWARD!

STAGE 1

- I found the WHITE Rubik's Cube logo center piece and it's on the bottom of my Cube.

STAGE 2

- I made a daisy on the YELLOW face by putting the WHITE edge pieces next to the YELLOW center piece.
- One at a time, I matched each edge piece to its center and made 2 turns of the FRONT face.
- I flipped my Cube over.
- I completed the WHITE Cross.

STAGE 3

- I held my Cube so the WHITE face is UP.
- I found a three color corner piece with a WHITE tile on it
- I moved the corner piece directly below the place it belongs on the top layer.
- I followed the sequence to move the corner piece to the top layer of the Cube.
- I put all 4 WHITE corners in their correct locations.

STAGE 4

- I turned my Cube upside down so the WHITE face is on the bottom.
- I made a vertical row of one color.
- I determined if the edge piece needs to move to the left or right.
- I followed the sequence to move the edge piece from the top layer of the Cube into the middle layer.
- I have all the edge pieces in their correct locations in the middle layer.

STAGE 5

- I matched the YELLOW edge pattern on my Cube to one of the patterns.
- I completed the sequence until I have a YELLOW Cross on the UP face of my Cube.
- I matched the YELLOW corners pattern on my Cube to one of the patterns.
- I completed the sequence until I have all YELLOW tiles on top of my Cube.

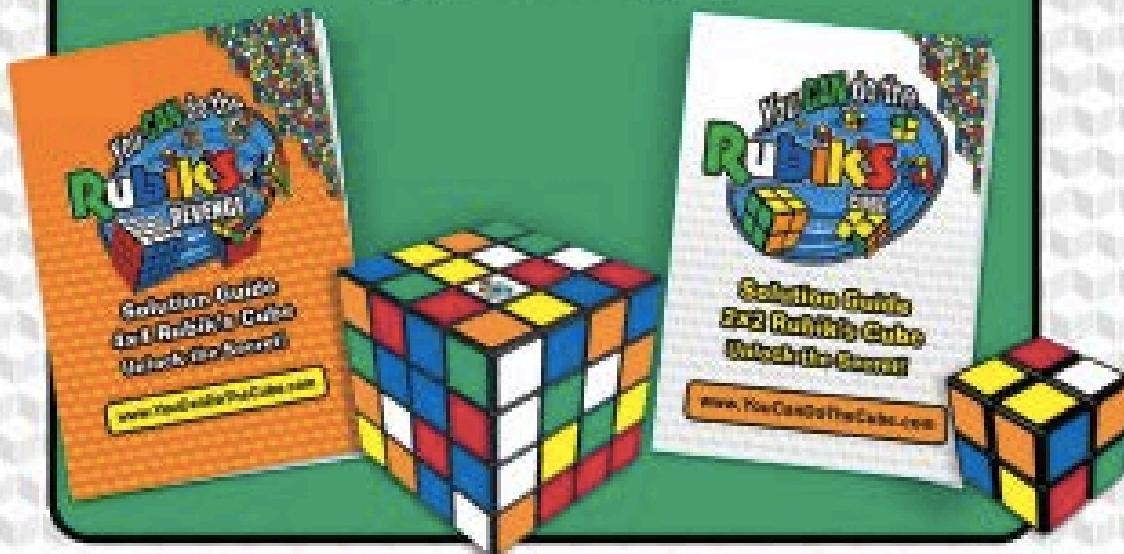
STAGE 6

- I matched two corners to their center color so they are in their correct locations.
- I held my Cube with the correct corners on the BACK face of the Cube.
- I followed the sequence to position all 4 corners into their correct positions.
- I counted how many edge pieces are in their correct locations.
- I identified what direction the edge pieces need to be moved.
- I followed the sequence to move the edge pieces into their correct locations.
- I SOLVED THE RUBIK'S CUBE!

Check us out online at

www.YouCanDoTheCube.com

Your next challenge:
Try the 2x2 or 4x4
Rubik's Cube!



- Borrow from our Cube Lending Program
- Purchase a Rubik's Cube Education Kit
 - Make a Rubik's Cube Mosaic
 - Host a Team Competition

Thank you to Tyson Mao, Jasmine Lee, and Dan Harris for your
inspiration to this guide. Thank you to all of the
Daisy Method contributors.